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A Manufacturing Collaboratory Case Study

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ABSTRACT

This report summarizes the experience with a collaborative tool intervention within a component design group of an automobile parts manufacturing company. A team of geographically distributed design engineers used Microsoft NetMeeting for a period of six months. Before and after survey data, combined with observational and interview data from site visits, showed low adoption of NetMeeting, despite favorable attitudes toward the application. The report explores factors related to low adoption and also evaluates the intervention strategy used in the study. Results suggest that key features of NetMeeting, specifically synchronous application sharing, were not as valuable as expected for collaborations that spanned time zones, but were more widely used for local collaboration. The report concludes that workarounds already in use within the target team, such as transmitting engineering drawings as email attachments, were sufficiently successful to inhibit exploration and adoption of alternative collaboration tools – even when these tools had desirable features as described by the engineers. The larger role of inertia and prior practice represents a key area for further exploration in terms of practice innovations for geographically dispersed engineering teams.

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1. INTRODUCTION

1.1. Background

Recent studies have found that a growing proportion of business teams involve collaboration with members who are not co-located (Kinney and Pankow, 1996). Much of the increase in long distance collaboration can be attributed to the evolution of communication technologies, including the phone, fax, and electronic mail, as well as the evolution of transportation technologies, specifically jet airliners. Despite these developments, the demand for more advanced collaborative technology continues as companies struggle to compete in dynamic, global markets. Much of the effort in producing new technology to overcome barriers of distance and time has focused on computer-based collaboration tools. For example, the rapid expansion of the Internet has made it possible for geographically dispersed employees to work with shared file servers, interact via desktop video conference systems, and edit documents and drawings in real time. For the most part, however, opportunities to exploit new collaboration capabilities have taken the form of single use applications, with little attention to gains that may be possible through integration of collaboration technologies.

An important exception to single use collaboration technology is the collaboratory concept (Finholt and Olson, 1997). A collaboratory is the "...combination of technology, tools and infrastructure that allow scientists to work with remote facilities and each other as if they were co-located (Lederberg & Uncapher, 1989, p. 6) ." A National Research Council (1993) report defines a collaboratory as a "...center without walls, in which the nation's researchers can perform their research without regard to geographical location -- interacting with colleagues, accessing instrumentation, sharing data and computational resources [and] accessing information in digital libraries (p. 7)." While the original

definitions of the collaboratory idea focused on use in scientific communities, a generalized form of these definitions applies to a broad array of activities. That is, a collaboratory represents the use of computing and communication technology to achieve enhanced access to colleagues, instruments, and information unconstrained by temporal or geographic barriers.

The first practical step on the path to collaboratories occurred with the opening of the first national data network in 1969, called the ARPAnet. The Advanced Research Projects Agency of the Department of Defense sponsored the development of this network. Four broad changes since the earliest days of the ARPAnet have created conditions conducive for collaboratory development. First, when the ARPAnet appeared its bandwidth was limited and network use was restricted to those institutions with ARPA projects. Today, commercial providers offer network access to thousands of organizations representing millions of users. Second, in the early days, network connections were scarce. Today, through the proliferation of personal computing and local area networks, network connections are ubiquitous. Third, early user applications had arcane interfaces. Today, most software products have intuitive, graphical interfaces that allow users to perform sophisticated actions without learning obscure command sequences. Finally, while early network use was confined to a small community of computer scientists, contemporary users represent a wide spectrum of commercial, academic, and educational users.

Collaboratory development occurs over decades, and requires an investment beyond the scope of this study. However, many existing and new tools, which typically form the core capabilities of a collaboratory, can be implemented to improve distributed collaboration on a smaller scale. In the nearly three decades since the birth of wide area computer networks, a rich variety of computer and network tools have evolved for the support of collaboration.

These capabilities can be defined as technology to link: people with people; people with information; and people with facilities. Examples of people-to-people technology include familiar applications such as electronic mail, file transfer software, and bulletin boards or newsgroups. New people-to-people technologies include desktop video conferencing, shared editors and whiteboards, and "awareness tools" designed to reproduce in a distributed network environment the social cues and information that are normally available only in a shared physical setting. Technologies to link people with information have recently experienced tremendous growth in sophistication and use. For example, the contents of millions of data files throughout the Internet have been linked via the World Wide Web (the Web). Graphically oriented applications for searching the Web, such as Microsoft's Internet Explorer, have become among the most popular computer applications ever written. Finally, technologies to link people to facilities include data viewers that display the current data, operational modes, and status of remote instruments.

Thus, the concept of the collaboratory can be useful in guiding and enabling collaboration on a smaller scale within communities, in organizations, and in teams. Furthermore, while most collaboratory development to date has been in the scientific domain, the enabling tools and infrastructure demonstrated by these scientific testbeds define a general set of capabilities that apply well to needs of the manufacturing sector. In the manufacturing sector, as in scientific communities, there is also demand for long-distance collaboration. Specifically, the push to do business on a global scale means that even small firms can have widely distributed facilities and suppliers. At the same time, increased interdependencies between manufacturers and their suppliers and accelerated schedules for bringing products to market make it imperative to achieve effective collaboration. As a result, key decisions such as design modifications, shipment

adjustments, or responses to customer demands for customization are increasingly made by managers and engineers who are not at the same site. The ability to support rapid decision-making among geographically dispersed workers can be greatly enhanced with the proper application of collaboration technology.

1.2. Role of the University of Michigan

Successful introduction of collaboration technology requires careful attention to principles and methods of human-centered design. The philosophy of human-centered design assumes that gains from the use of collaborative technology are possible, but not automatic. Therefore, to realize the potential of collaborative computing requires the integration of expertise about technology, about users, and about application domains. Through several collaborative projects in the domains of manufacturing, medicine, and community development, the University of Michigan has assembled a core team of computer scientists and behavioral scientists who have accumulated over 50 person years of experience with human-centered design methods since 1992. The focus of the University of Michigan approach to introducing collaboration technology is the deployment of existing or prototype applications into real field settings, systematic collection of rigorous empirical data from users of the applications, and subsequent incorporation of these data into further research. The cumulative experience of the Michigan team was applied in the current research to help translate generic collaborative technology into the manufacturing setting, as well as to identify and satisfy special requirements that arise as collaborative technology is introduced for manufacturing applications.

1.3. The research study

Collaboratories represent a potential transformation of how work is organized. Everyday use of collaborative tools will make long-distance collaborations qualitatively different and possibly better, while also introducing new tradeoffs and constraints in collaborative tasks. Understanding the impact of collaboratories and collaborative technology, then, is an important research goal, as reflected by current attention to this topic within the Manufacturing Engineering Laboratory at NIST.

Collaboratories have the potential to reduce the costs of spanning geographic and organizational boundaries. In organizations where working across geographic and organizational boundaries is framed as an opportunity, workers will be free to use collaboratory systems to exercise initiative in seeking and sharing expertise, with likely gains for the organization. For example, Hutchins (1995) has suggested that unhindered access by workers to organization-wide information systems might improve the efficiency of organizational information retrieval, with corresponding competitive advantages relative to organizations with less efficient retrieval systems.

Our research aimed to study the initial steps toward collaboratory development in a field setting, in an effort to contribute to the understanding of future collaboratory system development, and with the goal of examining the reduction of costs associated with distributed work. The objective of the research was to assess the impact of specific collaborative tools on current manufacturing practices. We aimed to accomplish this goal using observations of changes in manufacturing practices and processes related to the introduction of collaborative tools. Specifically, we planned to evaluate the effectiveness of collaborative tools on group performance within a single team in a large corporation. Our approach was to use empirical measurement to assess the collaboration needs of the user

team. We then planned to deploy available applications into the field setting, and subsequently collect empirical data to assess the impact of collaboration tool implementation.

1.4. Literature review and research expectations

The following section offers an explanation of the research questions we pursued embedded in the context of existing literature and research on collaborative technology. In this section we will also elaborate the difficulties associated with distributed work in organizations, the existing means of easing these difficulties, and the performance and interpersonal outcomes associated distributed work in organizations. Specifically, we will address:

- The benefit to organizations in using distributed teams.
- How this study contributes to research on collaboration tool use in distributed teams.
- Challenges to the effectiveness of distributed teams.
- Collaborative tools typically used to address these challenges.
- The particular collaboration needs of engineers.
- The expected effects of collaborative tool introduction on communication, performance and trust.
- A review of our expectations, based on the literature, as a result of collaboration tool introduction.

1.4.1. Distributed teams in organizations

As American industry has grappled with the challenges of global competition, rapid change and increasing complexity, organizations have dramatically increased the number of employees working in geographically distributed teams (Mohrman, Galbraith, Lawler and Associates, 1998; DeSanctis and Jackson,

1994). These distributed teams, also referred to as virtual teams, mediated groups and ad-hoc networks (Lipnack and Stamps, 1997; Mankin, Cohen and Bikson, 1996), face intense coordination pressure. Yet, distributed teams are critical to a global organization's success because they allow knowledge to be shared across organizational boundaries (such as countries, regions, functions and disciplines) and aid in the creation of new products and services (Lipnack and Stamps, 1997; Maznevski and Chidoba, 1998). Furthermore, having the option of forming geographically distributed teams offers organizations greater flexibility (Olson and Olson, 2000).

Distributed teams often rely on technology-supported communications, such as telephones, electronic mail, and video conferencing, more than face-to-face communications to accomplish their tasks (Kristof, Brown, Sims and Smith, 1995; Lipnack and Stamps, 1997). Advances in computer collaboration tools allow remote team members to collaborate on projects across geographies and organizations. For instance, these technologies facilitate necessary group activities, by supporting communication, scheduling, planning, task management and document sharing (Johnson and Anderson, 1997; Orlikowski, 1992). While a preponderance of such technologies currently exist, their impact on the performance of distributed teams has not been systematically examined.

1.4.2. Contribution to research on collaborative tools

This research aims to contribute to the evaluation of computer collaboration tools for distributed group work by examining the impact on performance following the implementation of collaboration tools. In addition, this study extends existing research on personal and organizational outcomes of geographically dispersed teams. Specifically, we examined the impact of collaborative tools on the work-related relationships of team members by

measuring changes in trust and organizational citizenship. Trust is more easily established among face-to-face than distributed group members due to the common ground developed from sharing a single context (Olson and Olson, 2000). Typically, trust evolves from shared experiences and norms (Bradach and Eccles, 1988; Lewis and Weigert, 1985; Mayer, Davis and Schoorman, 1995). In contrast, distributed group members must make an effort to develop and maintain trust (Rocco, 1998, Olson and Olson, in press). The fact of geographic distance from one's co-workers makes it difficult to monitor their behavior, and may exaggerate organizational dysfunctions such as absenteeism and social loafing (Jarvenpaa and Leidner, 1999; O'Hara-Devereaux and Johansen, 1994). Thus, trust may support group work and protect teams from the interpersonal challenges of distributed work.

1.4.3. Challenges to effectiveness of distributed teams

While geographically dispersed teams may seem an attractive solution to global organizations, they face numerous challenges to effective performance, including coordination and communication barriers. For instance, distributed teams using computer-mediated communication may take longer to complete tasks than face-to-face teams (Bordia, 1997; Daly, 1993; Hiltz, Johnson and Turff, 1986; McGuire, Kiesler and Siegel, 1987; Weisband, 1992). In addition, they may be less effective and more frustrated in trying to accomplish the higher-level decision-making tasks often required of design engineers (Straus and McGrath, 1994).

The team we studied faced the additional burden of delay in task completion exacerbated by geographic dispersion over multiple time zones. Specifically, when work hours overlap minimally, team members may need to wait in order to obtain information and therefore complete tasks. With less

synchronous time, virtual teams have increased coordination needs for interdependent work (Olson and Olson, 2000). Furthermore, with little synchronous time, virtual teams must maximize asynchronous means of coordination.

Thus, we expected that the distributed team members would encounter difficulties in coordinating work with their remote counterparts. Our study aimed to examine the baseline state of the team's coordination and performance, and the areas of difficulty that could benefit from collaborative tool intervention. Thus we asked: How do team members manage their work when synchronous time is minimal? What team or individual practices facilitate effective use of synchronous time? Which tools can ease the burden of geographic and time dispersion? We planned to conclude the research by examining the results of collaborative tool intervention on coordination, performance and trust.

1.4.4. Collaborative tools to overcome geographic dispersion

Two general categories of collaborative tools used by virtual teams are communication technologies and information sharing technologies. Communication technologies such as telephones and email are the means by which discourse occurs, and for the former, with little record. While it is possible to archive and structure email and telephone conversations, these are not always the intended use of these media. In contrast, information-sharing technologies represent, structure and store information, such as documents and databases, and usually support asynchronous activity (Mark, Grudin and Poltrock, 1999).

Typically, work teams need to use a combination of both communication and storage or information-sharing tools. Two powerful syntheses of communication and information sharing are currently available: Semi-structured

documents (e.g., Lotus Notes) and desktop conferencing (e.g.: NetMeeting) (Mark, Grudin and Poltrock, 1999).

Desktop conferencing enables real-time communication to be enhanced by data or application sharing. It allows geographically distributed teams to communicate and share information as though they were co-located (Mark, Grudin and Poltrock, 1999). Previous studies found virtual teams to be supported by a mix of email, telephone, and document exchange (e.g., Sproull and Kiesler, 1991; Zack, 1993, Wiesenfeld et al, 1998) and that desktop conferencing was helpful for groups with text-based tasks and graphical information needs (Minneman and Bly, 1991; Whittaker et al, 1993).

1.4.5. Collaborative needs of engineers

While most distributed teams may benefit from desktop conferencing tools, we expected that these might be particularly helpful to engineers. Studies of engineers suggest that a heavy reliance on visual and graphic material underlies the basic functioning of design engineering. Henderson (1999) describes the visual culture of engineering as one where co-workers communicate ideas via sketches, and often need to refer to drawings and designs to accomplish their work. Henderson describes the centrality of visual communication in engineering as follows:

The visual culture of engineering is more than the sum of its parts: the practices of sketching and drawing constitute communication in the design world. Other forms of knowledge and communication (verbal, mathematical, experiential) are built around these representations. Visual representations are so central to engineering design that meetings wait while individuals fetch drawings from their offices or sketch facsimiles on white boards. A shared visual literacy and ability

to read encoded meanings can facilitate coordination or foster conflict in collaborative projects (p. 25-26).

Thus, we anticipated that the collaborative tools used by engineers would be geared toward their visual culture to affect the team's functioning. We examined how distributed team members typically exchange information and communicate, and how the introduction of collaborative tools designed to aid in the exchange of visual information affects virtual team effectiveness.

1.4.6. Effect of collaborative tool introduction on communication, performance and trust.

Effective communication among individuals and across sites in distributed teams is the basis for both good team performance and mutual understanding among team members. For distributed team members to operate effectively in a rapidly changing environment, such as the one faced by the design engineers in our study who were constantly encountering new customer demands and specifications, informal communication is especially important to coordination (Herbsleb, Mockus, Finholt and Grinter, 2000; Galbraith, 1977; Kraut and Streeter, 1995). The exchange of information is typically operationalized as the informal communication network, which is distinguished from communication prescribed by the formal hierarchy in an organization. Information is a critical resource in organizations. The organization needs a system to gather and process the "news" that affects different contingencies in the organization. From this point of view, each individual is a source of information and an information processor. Furthermore, research indicates that teams with more frequent communication (email and face-to-face) were better coordinated, and subsequently performed better (Fussell, et al, 1998). Thus, we expected frequent communication should be associated with good coordination and performance in the team. Furthermore,

we assumed that collaboration tools that facilitate communication should have an indirect, positive effect on coordination and performance in the team.

A key issue in studying technology use in business settings is the impact it has on performance and process (Mark, Grudin and Poltrock, 1999). One of the difficulties encountered by researchers is gaining access to measures of team and individual performance. One means to understanding the performance of distributed teams is to assess coordination. For instance, Herbsleb and Grinter (1999) found that difficulties in coordination, such as knowing whom to contact for what, lead to serious problems in team members accomplishing their work. Furthermore, Herbsleb et al (2000) found that the most frequent consequence of cross-site coordination problems was delay in resolving work issues. They explain that work issues that might be resolved quickly in a collocated setting were sometimes delayed by days or weeks as distributed team members tried to establish contact with one another. Following from this research, we believed that coordination and delay were appropriate measures of performance for distributed teams. Furthermore, we expected that such performance difficulties should decrease as a result of collaborative tool introduction.

While communication in organizations is typically work-related, non-work communication is an important contributor to relationships among team members. Non work-related communication provides opportunities to develop emotional ties among co-workers that can lead to greater openness and sharing (Rocco et al, 2000). Thus, communication is one of the main mechanisms for enhancing trust in an organization (Sally, 1995; March & Simon, 1958). Thus, we expect that collaborative tools that enhance or facilitate social communication should enhance trust in the distributed team.

Developing mutual trust and understanding can be a challenge to the smooth functioning of virtual team. Laboratory studies of teams who primarily

utilize computer-mediated communication (as virtual teams generally do) indicate that understanding and perception of co-workers is reduced in these groups in comparison to groups who work primarily in face-to-face contexts (Straus and McGrath, 1994). In fact, communication partners are evaluated less favorably in computer-mediated groups (Kiesler, Seigel and McGuire, 1984). These studies corroborate further evidence gleaned from field studies regarding the difficulties of establishing shared understanding and trust in physically remote teams. In a geographically distributed team, members must work effectively with those from different backgrounds, functional areas, countries, and cultures. Each of these factors can lead to a lack of shared understanding between team members.

Furthermore, virtual teams face considerable obstacles in developing trust among their members. Remote team members are limited in their social interaction with one another, and are unable to freely communicate. In contrast, co-location reinforces opportunities to develop social similarity, shared values and expectations (Latane et al, 1995; Olson and Olson, in press). Where shared social norms and experiences facilitate the development of trust (Mayer, et. al, 1995), distributed teams are at a distinct disadvantage.

In addition to the importance of trust in co-located teams, it is even more important to making distributed teams effective. Remote team members must rely on individuals whom they can not easily monitor or control. In the absence of direct control of subordinates and coworkers, trust takes on increased importance (Mayer, David and Schoorman, 1995; Spreitzer and Mishra, 1999). Establishing trust is essential to ensuring virtual team cooperation (Handy, 1995). For instance, mistrust in virtual teams can result in defensive and counterproductive behavior (Rocco, Finholt, Hofer and Herbsleb, 2000). Therefore, we believe it is important to consider the creation and maintenance of trust a relevant outcome of distributed teamwork

We believe that collaborative tools can play a role in the development and maintenance of trust in distributed teams. Specifically, we feel that by introducing collaborative tools that allow for the exchange of visual information, the frustrations of communicating across spatial and cultural barriers may be reduced. A body of research supports this assertion. For instance, research indicates that visual representation of a complex artifact (such as a CAD drawing or photograph of an automotive part model) helps team members communicate when referring to the artifact (Farmer and Hyatt, 1994; Nardi, Kuchinsky, Whittaker, Leichner and Schwarz, 1997; Olson and Olson, in press).

Furthermore, by allowing engineers to share the visual representations and meanings common to their profession, collaborative tools may enhance the development of mutual trust among remote colleagues. Based on the work of Clark and Brennan (1991), Olson and Olson (2000) describe how features of a tool such as NetMeeting may facilitate the development of trust. They explain that while NetMeeting does not provide the complete context for work interactions, it is useful in establishing common ground about the object of work. Team members may speak to one another remotely using audio conferencing, but make use of technologies like NetMeeting for remote access to shared work objects, in addition to gesturing with the use of a telepointer and markers. Thus, we expect that team members should experience greater trust in one another following the introduction of collaborative tools than at baseline.

1.4.7. Review of research questions and expectations

- To assess the work and collaboration practices of team members we planned to ask: How do team members manage their work when synchronous time is minimal, what team or individual practices facilitate effective use of

synchronous time, and which tools can ease the burden of geographic and time dispersion?

- We expected that implementing collaborative tools that enhance visual communication should be related to improved performance.
- We expected frequent communication should be associated with good coordination and performance in the team. Furthermore, we assumed that collaboration tools that facilitate communication should be associated with improved coordination and performance in the team.
- We expected that such performance difficulties should decrease as a result of collaborative tool introduction.
- We expected that collaborative tools that enhance or facilitate social communication should enhance trust in the distributed team
- We expected that team members should experience greater trust in one another following the introduction of collaborative tools than at baseline.

2. DESCRIPTION OF RESEARCH

2.1. Context of the case-study

2.1.1. Collaborative Product Development

For many manufacturers, the concept of concurrent engineering has been applied to the product development process as a systematic approach integrating the product design and related manufacturing, maintenance and support processes (Kim et al., 1999). Many different engineering disciplines can be involved in a complex design process, e.g., electro-mechanical aspects of engineering design require both mechanical and electrical engineers. Designers, engineers, and managers must make decisions based on analysis from shared data from many sources. Typically, teams working together, discussing the data, identifying and resolving problems, and generating new ideas and design options make these decisions. In fact, today's product development efforts are dominated by

communication, teamwork, coordination, meetings, negotiation, and conflict management (Walton, 1997). While each engineering team may have company-specified or individual approaches to product development, they will likely include elements of customer requirements, product definition, feasibility/concept/detail design, analysis, manufacturing, and evaluation. (Gowda et al, 1999)

One impact of the globalization of manufacturing is the growing need for product development to occur among teams that are not co-located, driving the use of collaborative tools (Steves and Knutilla, 1999). Collaborations among product development teams are further challenged by “round-the-clock engineering” with co-workers in multiple time zones and with co-designing occurring with overseas partners. Many companies are outsourcing those activities that they do not do well, leading to further partnerships and data sharing demands.

According to industry experts (Kandarian, 2000), collaborative product development – the process of sharing information in the design and creation of products to greatly speed manufacturing – is occurring now. There are a variety of groupware tools being developed, considered, and used for collaborative product development. These tools strive to enable application sharing, co-authoring, three-dimensional geometry visualization, coordination of resources, synchronous and asynchronous communication, desktop conferencing, work process modeling and management, product data sharing, knowledge sharing, distillation of information from distributed resources, deployment of advanced design methods, and conflict management. All of this may be desired, plus minimum maintenance, low cost, and transparency of the technology to the end users. There are several additional drivers for incorporating information technology to enable collaboration (Ward 2000), such as:

- Time and money savings associated with reductions in travel.
- Price per seat for users of groupware systems is falling.
- Groupware technology continues to improve.
- Shortened product development cycles and the proliferation of information is inducing organizations to look for new approaches to communication, collaboration, and knowledge management.

The use of information technology for collaborative product development poses certain technical challenges, chief among which are data security and interoperability of collaborative tools. Yet, despite these barriers, manufacturers are realizing that the ability to share designs, specifications and other crucial information can only be done by sharing that information throughout the entire manufacturing process, and this requires electronic collaboration.

It is one thing to assess the usefulness of tools for collaborative product development. It is quite another to deploy and effectively use these tools to shorten product development cycles and improve quality in today's global environment. There are many factors beyond the technology that impact collaborative product development. These include, but are surely not limited to:

- The effectiveness of information and knowledge management
- Organizational structure and management endorsement
- Product technology and complexity
- Human behavior, social competence, cultural differences

2.1.2. The Product

The research site supplies parts to the automotive industry. We studied a product development team that was integrating previously independent teams to develop a new, innovative automotive subsystem. There were 4 major subprojects (electronics, hydraulics, system integration, mechanical) with at least 60

subprojects beneath those. The product being developed was very software intensive and involved a new form of interaction between the hydraulic and mechanical systems. When we began the study, the project was in the concept stage. During the course of the year, it progressed into the product intent stage, and moved to the product release state at the conclusion of our study.¹

The design, development, test, and manufacture of this subsystem involved integration of many components, requiring collaboration among groups in four countries, many of whom had never worked together. For instance, the component design occurred in Australia, Germany, and North America. The Australian unit belonged to a subcontracted partner organization that contributed to the early design work. Testing and application engineering occurred in North America and Germany. The main manufacturing site was in France. Research and development and administration were located in North America. While the company planned to increase cross-division collaboration in the future, it was progressively seeking to exploit information technology to support these plans.

The product thus involved a cross-divisional effort to design, test and manufacture an automobile component. The component was thought to become an innovative and highly competitive product in the automobile market. It would resolve several system issues into a single product.

2.1.3. *The Research site*

The research site was an automobile parts supply company serving vehicle makers worldwide resulting in over \$2.7 billion in sales. The company, which we will refer to as "Auto1," has over 14,000 employees at 60 locations in 13 countries. Representatives from this supplier approached us requesting participation in this research. They were initiating a new program for a new-

¹ This information was provided by an upper level manager at the conclusion of the study.

concept OEM part. Annual sales of over \$1 billion were projected. The catch, and the driver for collaboration technology, was that product development would require a successful union of expertise among previously disparate business units within the corporation. These business units would be working together for the first time across multiple time zones, addressing cultural differences, political and organizational challenges, and inconsistent information technology capabilities. Customer requirements would be vague and would change. New people would be joining the team as the program expanded. This company had the foresight to know that they would require the help of collaboration technologies for this project to enable success, and they also knew that this would likely be the first of more cross-business programs. The time to embrace collaborative product development and the tools that support it was here.

In partnership with company managers, we selected a single group of approximately 50 employees (35% managers) as the participants in our study. This group comprised several distributed teams spanning four countries in three continents involved in a single project. We have given these sites, and the employees at the company, pseudonyms to protect their privacy. Thus, we will refer to the team as the CAR team, the two divisions as Division A (the dominant division of the team) and Division B. The sites will be described as being located in the United States or in Western Europe. Three sites were in the US (Division A's US site, Division B's US site, and the Headquarters US site), two sites were in Germany (the German product development site and the German manufacturing site), and one site was in France (manufacturing). In addition, the Headquarters and Division B managers considered an Australian subcontracting partner organization to be part of the team, especially in the inception of the project. We will refer to this boundary group as the Australian site. The team was selected

because it was early enough in the production process to remain intact throughout the life of this study.

While this group was selected as a highly functioning team ready to adopt new technology, the team faced several potential challenges to collaboration inherent in its work structure. In general, this was a large, dispersed organization, and new team members were unfamiliar with their colleagues prior to joining them on the project team. A few participants expressed a sense of isolation due to lack of co-location (even at the same site). For example, one participant told us: *I feel like I don't know what is going on. I don't know who other people are (here in US). ... For many products and projects -- need information about other project's work and customers. I don't know what the person on other side of cubicle is doing.*

As a new and growing project, team members perceived it as understaffed. Team members were under further pressure from management and the customer, due to frequently changing specifications, and falling behind schedule. In addition, the workflow was divided across two sites: the product development efforts were primarily in Europe, while test and build efforts were primarily in North America. The two sites were not used to this unique global arrangement. Furthermore, the organization was divided into several technical leadership “chains of command”, whose multiple leaders did not always understand each other, and were not used to openly sharing problems. For example, one participant explained that management...

Need(s) to elevate openness and communication more ... People haven't worked in this type of arrangement before. We are not sharing all details and problems, and they (other division) are not sharing problems with us. It would be helpful if both sides would share problems.

Thus, this particular industrial team offered many collaboration challenges. The integrated team was new and expanding, with a growing staff of newly hired designers and engineers supporting the core group. Engineers, designers, and managers were required to share a variety of data types among these dispersed teams, including design data from different CAD applications, prototype test data, design analysis data, and manufacturing specifications. The customer requirements for this new product were not stable and the customer was not geographically near many designers, posing new design challenges. While some members of the team were co-located, most were geographically dispersed, driving coordination challenges that were further complicated by time-zone differences. Cultural and language differences among the North American, German, French, and Australian groups were encountered and addressed, for many, for the first time. Below, we describe some of these issues in greater detail.

2.1.4. Power and political issues within the team

We found many political issues related to the cross-divisional nature of this project. For instance, team members described communication problems within the team and across divisional boundaries. They mentioned that the sites were not used to interdivisional work, and many commented on how they or others avoided using technology that could potentially help them collaborate. Evidence of this was found in the following:

- The product development efforts were primarily in Germany, while test and build efforts were primarily in North America. One team member said that at the beginning of the study, team members did not adequately share problems. He described a need for more openness and communication between the sites, and that the two sites were not used to this unique (global) arrangement.
- Another team member mentioned that it was difficult getting all participants at regular, videoconference meetings. People did not seem used to sharing problems in a regularly scheduled way.
- Team members seemed to “hide” behind email. It seemed there could be more open communication, better details using the telephone, but team members seemed to use email when a phone call could have been better.
- One US manager created a web site for sharing work materials. He commented that others did not check the web site to see what was new. Management used it for briefings. Another team member mentioned that he thought engineers did not use the site because they did not want to share “dirty laundry” on the web site for others to see.
- Some team members expressed a sense of isolation, which inhibits communication. This could be due to lack of co-location (even at the same site), lack of knowledge about who is on the team, and lack of information flow.
- Another member explained that remote communication could be improved if the German product development site adopted collaborative tools like the Internet (see Appendix K, interview citation 1).

There was also further evidence of divisional conflict and political issues. For instance, team members said the following:

- Because the organization was new, large, and dispersed, there were several technical leadership “chains of command.” These multiple leaders did not always understand each other.
- One team member described this project as "hugely different" from others he had worked on at the company because it was a joint venture with the other division, and based in Europe. While the project had begun in the team members division (Division B), the seat of power and responsibility had shifted to the other division (Division A). As a result, he described working on the project as "very political" and said: "I was absolutely scorched by those guys back when it was my project. (They were) hugely critical. I think it is from their culture, they put a magnifying glass on all of our problems and make them worse. Even when their problems are bigger." Evidently, there was underlying resentment between the two divisions in this project.
- One participant from the Australian site explained that the engineers at the German product development site were inexperienced and relied heavily on the Australian site, causing resentment (Appendix K, interview citation 2).
- Another team member described the divisional differences more positively, saying "(divisional) differences are interesting because people lack the core knowledge about each other's work, but everyone learns from each other..."
- One German team member described the fact that the European location had become the center of action. He said, “The fire is burning here (in the German product development location). Once you leave you can only see the light." Another team member echoed the sentiment that the center of activity was in Europe, but that a fair amount of work will need to take place in the US Division B site (Appendix K, interview citation 3).

- There were further disagreements between the divisions regarding the boundaries of team membership, with divisions disagreeing on the status of the Australian site (see Appendix K, interview citations 4 and 5).

2.1.5. Cultural differences

We expected the possibility that cultural differences between sites might arise in a global team such as this. A few team members commented on differences caused by language and work style. For instance:

- Some team members commented that language differences caused some communication problems that were best handled with face-to-face meetings. They perceived email and telephone interactions working better after there has been an initial face-to-face meeting.
- Team members described cultural differences in decision-making. One participant explained that Germans tended to rely on consensus whereas North American individuals pushed their decisions through. However, younger Germans were more apt to follow North American model.
- One Australian participant said of his German counterparts that: "...some of the (cultural) issues between us are subtle. We are trying to change an attitude – like general politeness, things like, when they come here, we take people to dinner and show them around and vice versa, since the Germans wouldn't do that before. This is coming up because people are at the end of their tether."

2.1.6. Work and management styles

Team members often attributed work style differences to the national culture of the other team members, yet it is unclear whether the features they described were

true of the national culture in general, or the organizational culture of the subgroup. There is little evidence in the academic literature to support the claim that these are national differences, thus we represent the participants' opinions here. For instance, one German engineer commented on the frustration working with Americans (included below), whereas Americans and Australians had equally frustrating but different cultural issues with the Germans (Appendix K, interview citations 6 and 7).

- "The most frustrating thing was that we'd (3 German team members) talk to (US team member) about how we would do something, and we'd all agreed and usually, we then went on, it was 6 o'clock (in the evening in Germany) and he would go to work. And the next morning we'd have a revised drawing in our email system. Consensus would be reached, but then (US team member) would consult with his boss, reach a different conclusion, start working, and what would be there for review in the morning would be different from what was expected. Then, we had to wait until lunchtime to call him and ask him, "What have you done? Why did you change that?" then discuss it again, and so on. That was kind of frustrating. "

2.1.7. Technical Issues

We discovered that at the beginning of the study, team members had both helpful and harmful norms in their use of media to support their work. In particular, participants mentioned several points of frustration in using technology to work with others within their team. For instance:

- Participants mentioned that tasks assigned over the telephone were more frequently dropped than those made by email.

- File transfer was difficult, did not always work, and was time-consuming. It was difficult to get MIS help when things went wrong, permissions were “lost”, and data was sometimes lost or not transferred.
- Related to file transfer difficulties, there was a sense that MIS was not committed to support the technical team, but things were improving.
- There was a perceived resistance to Internet technology (i.e., website), especially its security, by German senior management. For instance one US participant said of working with the German team: "One thing I found out was a lot of negativism about IT. Management would criticize us for using a secure server, but they had nothing to back it up (in other words, they were wrong, the server was fine). They even forced us to remove things from the server once. I would say this was pretty active resistance to new technology."
- Different CAD packages were used by different collaborating groups, creating problems in addition to the file transfer problems described above. There was resistance to learning the “other” team’s CAD application. (A North American designer explained that 2-D software was easier than 3D software for transfer between programs. He claimed that ProE (used in Germany) constrains everything, as it is necessary to dimension everything, which is time-consuming, and the North Americans don’t think of all those things (dimensioning) first. (“It’s a step that I won’t do.”) CATIA was easier. On the other hand, the Germans take time to dimension everything in ProE. The North American designers did not have time to learn a new program (ProE) or learn how to dimension. Other team members mentioned this problem as well, in terms of the difficulty of gaining common ground among all the different types of software (Appendix K, interview citation 8), and not being kept abreast of changes in software use (see Appendix K, interview citation 9).

An Australian team member compared the German and US team members to those in other companies. He explained that the German subgroup seemed to have particular problems with technology adoption, which he perceived to be the fault of management being technology averse and poor support from information technology staff (see Appendix K, interview citation 12). He further explained that he believed that the situation was improving somewhat (see Appendix K, interview citation 10) and that he believed that engineers at his level (managerial) and below would be interested in learning new technology skills, but that the IT support was not available to them (Appendix K, interview citation 11).

2.1.8. Collaboration processes within the team

We began this study with an investigation of the collaborative processes in place. The approach we used to identify these processes are described in detail in the sections below (for example, refer to the User-centered Design, and the Evaluation sections of the report). Briefly, most of the team members used a variety of media to collaborate with local and remote colleagues. They used email, telephone, faxes, travel and overtime regularly. Less consistent use of other tools, such as PC Anywhere with FTP to share files, digital cameras, voicemail, electronic calendars, video conferencing and an internal web site was also described by CAR team members. For more information and greater detail on the use of these tools, refer to section 2.3 "Baseline interview data and observations" below.

2.2. Description of the study and evaluation approach

2.2.1. User-centered Design

We began the evaluation with a web-based survey of the distributed team members. The survey questions focused on an assessment of the utility of the

collaborative tools introduced to the team, and baseline measurement of the outcomes of team effectiveness and mutual trust. In addition, we conducted interviews with a subset of the team members to determine further collaborative needs of the virtual teams. These interviews were used to plan further implementation and support of the teams' collaborative needs. The goals of the interviews and survey were to create an initial data set against which future data could be compared. In addition, our goals were to monitor team changes as a result of collaboration tool intervention, to assess the value of various collaboration tools for advanced product design, the extent of differences in collaborative work across sites, and specific difficulties in cross-site work.

2.2.2. Interview method

The purpose of the interviews was to evaluate the current work practices of the distributed team, and to determine possible areas of weakness that could benefit from collaborative tool intervention. We distributed a document titled "Promoting Project Team Collaboration" (see Appendix A) on October 4, 1999, that explained our research approach as such: "The research exploration will include: 1. Analysis of current work practices most impaired by geographic dispersion of the engineering team. 2. Selective introduction of collaboration tools to match these practices. 3. Assessment of the cost and effectiveness of these tools."

We planned to gather survey data from the entire team, and select a smaller sub-sample for interviews. The reason for this method is twofold. First, coordinating schedules of participants and conducting interviews is labor-intensive and time-consuming. At the time this decision was made (October 1999), the project was scheduled to end September 2000. Conducting interviews with each of the 50 team members, and subsequently analyzing the qualitative

data, would have interfered with the goals of implementing collaborative tools and conducting follow-up data collection, and would have threatened the quality of our research.

Second, we expected to use the information gleaned from the interviews as pilot data, intended to shape the questions we would ask in the surveys. As such, we chose to gather information from key informants, individuals whose point of view or insight might be particularly helpful because of the position they are in (e.g., management, remote team member, etc.), or skills they might have (e.g., use of current collaborative tools). Thus we selected a subgroup of individuals from the selected team group (e.g., sampling by organizational status and task responsibility), whom we believed, and management suggested, could give us this information. While most of the interviews were conducted prior to the survey development and distribution, a number of the interviews occurred concurrently with, or following the survey distribution. Thus, a few of the interviews actually informed the survey, most provided information that was not found in the survey (for example, about the political or cultural issues in the team), or offered a richer explication of related topics.

Twenty four interviews were conducted, 10 in one site in North America, 11 at one site in Germany and 3 via phone to Australia. The interviews ranged from 20 to 40 minutes, and were conducted at the participants' workplace, usually in an assigned meeting room. All face-to-face interviews were audiotape recorded.

In accordance with the standards set by the University of Michigan's Institutional Review Board for Studies Involving Human Subjects, we also protected the participants in the study from undue disturbance. Thus, we planned to have minimal repercussions on members of the company as a result of this research exploration. We also promised that across all of these data collection

efforts, identities of the research site and specific workers will be appropriately concealed in resulting publications and all data collection. Measures were taken (such as providing participant ID numbers and separating these from participant's names) to ensure that participants could not be identified. Furthermore, we promised to conceal the identity of the organization and as well as details of the product the team was developing in our work. This decision was made partly as a result of the standards set by the University of Michigan's Institutional Review Board for Studies Involving Human Subjects, and through legal negotiation and contract with the research site.

The interviews with the team members and management addressed work role and background, identification of local and remote collaborators, the current means of communicating with remote collaborators, and tools, obstacles and opportunities for remote collaboration (see Appendix L for interview protocol). We asked these questions following the user-centered design principles, in order to gain an understanding of the team members' current work practices. These questions were aimed at also uncovering established norms and potential barriers to future collaborative tool introduction. The interviews were semi-structured in format, where the interviewers allowed for conversation with the informants so that informants could expand on topics most relevant to themselves and open the possibility for gaining additional unforeseen information.

2.3. Baseline interview data and observations

Interviews with team members both supported the survey findings and offered further insights about the manner in which team members collaborated at the start of the study. We found that most team members used the following methods for collaboration:

- Email. Microsoft Outlook was the supported email system and offered secure email exchange. Some interviewees described team members as “hiding” behind email, by choosing email instead of the telephone, when they could have more open communication or better details using the telephone. However, interviewees also described email serving as a valuable record. For instance, one interviewee mentioned that tasks assigned on the telephone were more frequently dropped than those made by email. Finally, email was cumbersome for exchanging large amounts of information. For instance, file transfer was described as difficult, inconsistent and time-consuming. Team members reported difficulty obtaining MIS help with problems, permissions were sometimes “lost”, and data was sometimes lost or not transferred. Related to file transfer difficulties, there was also the sense that MIS might not be committed to supporting the technical team (but things were improving).
- Telephone. The telephone was most often used to discuss coordination issues and plans, for acquiring further information or details, and for clarifying issues mentioned in email. Some respondents used speakerphones as well.
- Fax. Interviewees used faxes to simply and quickly exchange sketches or other materials.
- Travel. Team members often traveled between North America and Germany (primarily) in order to facilitate working together. Language differences caused some communication problems that were best handled with face-to-face meetings. Email and telephone interactions were described as working better after there had been an initial face-to-face meeting.
- Overtime. Americans often used overtime to synchronize work with German counterparts. German labor laws constrained German CAR team members to 8 hours work per day.

In addition, the following means of collaborating were also used by a subset of the interviewees:

- PC Anywhere. This application-sharing tool was used over the VPN with collaborators' IP addresses. It was used to share CAD applications, and to facilitate discussing a visual problem while speaking on the telephone.
- FTP. This application was used to share files, in conjunction with PC Anywhere.
- Digital camera. The camera was used to take photographs of an annotated drawing. These were then sent as email attachments to an email and used to discuss specific engineering or design issues at hand.
- Videoconferencing. These were used for a few regularly scheduled meetings. Interviewees reported difficulties in setting up the videoconference (in the sense of both technical set-up and scheduling). It was also difficult getting all participants to attend regular videoconference meetings. Interviewees mentioned that team members were not used to sharing problems in a regularly scheduled fashion.
- Cellular telephones. When working with team members who travel frequently, securing a cellular telephone number offered greater means of contact.
- Voicemail. Participants mentioned that there was a low response to voicemail, limiting its effectiveness.
- MS Outlook Calendar. This application could be used to view other people's schedules. This was not consistently used across the organization, limiting its effectiveness.
- Internal web site. A web site was created by the manager of one division involved in the project to file presentations and drawings. The site was not regularly viewed and its use was not widely understood. Interviewee's

impressions were that team members did not check the web site for new material. Rather, it was primarily used by management for briefings.

Engineers were also concerned that the web site would contain “dirty laundry” that others might see. Furthermore, there is a perceived resistance to Internet technology (such as the web site), especially to its security, by German senior management.

- Post-its on door.
- “Vision software” from Parametric Technology. This software was newly purchased at the time for the study (12/99). It was used for CAD application sharing, and to replace PC Anywhere.

Finally, the interviews were valuable in uncovering further issues regarding collaboration within the team. For instance, interviewees described the difficulty of collaborating in a new project, workflow coordination problems and cultural differences in decision making affecting communication. For a discussion of the collaboration issues facing the team, refer to sections 2.1.3 (The Research site), 2.1.4 (Power and political issues within the team), 2.1.5 (Cultural issues), 2.1.6 (Work and management styles), and 2.1.7 (Technical issues).

2.4. Requirements for collaboration

Based on the analysis of the interviews, we identified the following requirements for collaboration.

2.4.1. Synchronous communication

Synchronous communication could be improved to aid in the team’s functioning. For instance, tools to improve mutual understanding of the material when discussing sketches, designs or other visual material with team members (e.g., ability to simultaneously point to problem areas) would be helpful for

designers. In addition, knowing when people are at their desks (e.g., since everyone logs in when at work), and knowing when they are logged in would aid in locating co-workers.

2.4.2. Asynchronous communication

Team members currently exchange task requests, data, test data, meeting summaries, reports, designs, proposed design changes, and sketches. The formats used include jpeg, gif, Autocad, Excel, and Word files. For improved collaboration, the team would require improved speed, ease, consistency (of method) and accuracy of file transfer function. The ability to identify or describe visual details, which are common in design work, is also a requirement for collaboration.

2.4.3. Time zone issues

Disparate time zones create difficulties for synchronous and asynchronous collaboration. Team members could maximize use of synchronous time shared with co-workers in other time zones. In addition, a toll that would minimize delays in work encountered when working with remote collaborators would facilitate collaboration.

2.4.4. Scheduling

To improve collaboration, it would be useful to know the availability of local and remote co-workers. Tools that could aid in scheduling common meeting times with both local and remote co-workers would be an asset. Maintaining the privacy of personal schedules was a requirement of any collaboration tool that might be implemented.

2.4.5. Security

Adequate security was a requirement of any feasible collaborative tool. Design information (but not verbiage) needed to be secure. A system that could record the identity and time of common file access (e.g., access log) and could control versions of documents would be useful.

2.4.6. Design specific

Design specific requirements for collaboration included improving the accuracy and speed of CAD data translation. Software used includes CATIA, ProCAD, ProE, ProE20, CADAM, Mechanical Desktop, SIM-PRO, and software to transfer CATIA to ProE. In addition, engineers needed access to most recent customer specifications and changes. With this project especially, the customer was changing the specs frequently.

A tool that could capture why a change was made would be helpful. This was especially important when changes were made in one time zone and the drawing with the change was sent to another time zone. In general, tools to exchange knowledge completely and quickly among CAD designers and engineers were needed. This is to replace the verbal discussions that were delayed or did not occur because of lack of co-location and time differences. This becomes even more important in the final stages of production design, when communication grows in frequency and criticality. It is vital to have the ability to talk over drawings. For instance, one participant mentioned that email text discussions have less immediacy than a phone calls and it's easier to slide on follow-ups. If you are co-located, the knowledge exchange is much faster and complete. Another engineer explained that when using email, unnamed components must be described to identify them (like the second bow in the tube,

etc.) since not all parts have names. It seemed very difficult to discuss this over email because communication is tedious and slow. Finally, it would be helpful to have the capacity to exchange sketches. Concept designers generally like to work with paper first, and use sketches to discuss things (younger designers, who may be more comfortable doing this on a computer, usually do not do concept designs).

2.4.7. Other

Knowledge of team members identities (who they are and their roles), as well as what other work is transpiring was requirement for collaboration. This was especially crucial as new people joined the team. It would be useful to know from whom an email is coming, that person's role, background, and position in the organization, e.g., an organization chart with pictures and biographic information. With a project this large, it would be useful to get a sense of the "big picture" of how team members roles interact. Finally, knowledge of customer requirements would be a valuable contribution. Because the customer is distant and requirements are often relayed through several people, they are not always fully understood by designers. In this project especially, customer specifications were frequently changing.

2.5. Pre- intervention questionnaire

All 50 members of the team were invited via email to participate in the study and complete the web survey. No incentives for participating in the study were offered. Thirty-four out of 50 (68%) employees completed the baseline survey from 6 geographically distributed sites, in 3 countries. Most respondents (65%) came from European sites (18 from Germany, 4 from France, 12 from the United States) (see Table 1 in Appendix F for further information regarding

sample distribution). Respondents were predominantly male, of a mean age of 35 years (s.d. = 8.46). They had been at the company a mean of 6.4 years (s.d. = 8.91).

The web survey consisted of 48 questions in 6 sections covering background and demographic information, technology adoption motivation, communication patterns, coordination, performance and trust.

2.5.1. Background items

The background items included A) demographic information, B) job satisfaction, C) English speaking skills, D) location and E) workstation.

A) Demographic information was collected and used primarily to control for extraneous influences on our statistical analyses. Each of these demographic characteristics has been shown to have possible effects on employee responses regarding an organization (Tsui, Egan & O'Reilly, 1992). Specifically, we collected background information to determine the participants':

- age
- gender
- nationality
- tenure in the organization, and
- job title.

B) Job satisfaction may be related to an individual's performance at work, and has been found to be linked to extra-role behavior, such as organizational citizenship behavior (Bateman and Organ, 1983). We controlled for job satisfaction by asking:

- "How much do you like your job?"

C) We also asked participants whether they were native English speakers, and their level of skill in speaking and reading English. This question was aimed at controlling for possible effects due to lack of comprehension of the survey. Poor English comprehension was found to be a problem in other studies of cross-national distributed teams (Rocco, 1999).

D) To get further information about where team members worked, we asked them where their primary office was located. In addition to being able to glean general information about the dispersion of team members, we had reason to believe that site location might characterize a number of important differences among participants, such as office and national culture (Rocco et al, 2000). In order to gain an understanding of the subgroups within the team, we asked participants to indicate:

- "On which CAR project are you currently working?"

E) All of these questions were asked in to gain general information about the team members and how they conducted their work. This information was gathered to enable the research team to make judgments about which collaborative tools could feasibly be implemented within the team. To understand the level of technology available to team members, possible areas of hardware incompatibilities and the extent to which participants have privacy in their workplace, we asked participants to:

- "Please indicate the type of workstation you use most of the time (Windows95/98, Windows NT, HP Unix, Sun Unix, IBM Unix, SGI Unix, X Terminal, Macintosh, Other)."

- "Please select the description that best describes your primary office (Solo, shared office, open plan, other)."

2.5.2. *Independent variables*

The independent variables included items that asked about A) the participants' motivation to adopt new technology, B) work-related communication patterns, C) non-work related communication patterns, and D) workflow.

A) In order to understand the baseline level of receptivity to potential collaboration tool interventions, we measured the motivation of team members to adopt an electronic calendar, availability and presence tools, and a shared mark up tool. Participants rated their motivation to adopt each type of technology on a 1 to 10 scale, with 10 being most likely and 1 being least likely. This information was gathered to enable the research team to make judgments about which collaborative tools could feasibly be implemented within the team. For instance, we would proceed cautiously with implementing a tool that most respondents rated as "unlikely" for them to adopt. These items have been used diagnostically in other similar studies (e.g., Walsh, Kucker, Maloney and Gabbay, 1999).

Thus, we asked team members to indicate:

- "How likely would you be to adopt for regular use software that lets you and your co-workers share information about your schedules on a common calendar?"
- "How likely would you be to adopt for regular use software that lets you lets you integrate caller ID, click to dial, and conference calling from your workstation?"
- "How likely would you be to adopt for regular use software that lets you lets you and your co-workers share information about availability and presence?"

- "How likely would you be to adopt for regular use software that lets you and your co-workers simultaneously mark up a drawing when you are at your desks?"

B) Effective communication among individuals and across sites in distributed teams is the basis for both good team performance and mutual understanding among team members. For distributed team members to operate effectively in a rapidly changing environment, such as the one faced by the design engineers in our study, informal communication is especially important to coordination (Herbsleb, Mockus, Finholt and Grinter, 2000; Galbraith, 1977; Kraut and Streeter, 1995). We collected information on communication patterns through several different measures.

First, we asked participants to select up to 15 co-workers that they typically interact with. Studies of social networks found that individuals typically determine the size of their social network to be around 34 individuals (Sudman, 1985). In addition, previous experience in our laboratory found that individuals typically list more than 10 co-workers in name-generator questions aimed at determining their network interactions. Thus, we felt confident that limiting participants to 15 others was reasonable, and would yield the most salient co-workers in their environment. Furthermore, this list of co-workers was transferred to further questions in the survey. We wanted to limit the burden of required of participants in answering the survey to avoid incomplete responses. Once participants had selected their initial group of co-workers, we measured the self-reported frequency of interaction with local and remote team members via face-to-face, email, telephone, conference call, voice mail, fax, and videoconference. Specifically, the survey instructed them to:

- "Consider your work on the CAR team. Please choose those people you most often communicate with for work-related reasons. Selected names on the list will appear automatically in following questions. If the name of a co-worker is not listed, please type in his/her name."
- "For each co-worker you selected, please provide the number of times in a typical week that you communicate for work-related purposes face to face, by phone and by email."
- "For each co-worker you selected, please provide the number of times in a typical week you communicate for work-related purposes by conference call, by video conference, or by collaborative tools (e.g., application sharing tools like PC Anywhere or NetMeeting, which allow two team members to simultaneously view and modify common documents or drawings)."

To further measure face-to-face communication opportunities, we also asked participants how many days were spent visiting remote sites to further. Specifically, we asked participants to:

- "Estimate the number of days you spent at each of the following sites during the previous six months (June 1, 1999 - November 30, 1999). Please enter the number of days by each site. Leave the site of your primary office blank. Enter zero for sites you did not visit."

Finally, we posed a summary question, which we could also, compare to previous questions to crosscheck the data. We asked participants to:

- "Indicate the frequency of your work-related communication across all modes (e.g., face-to-face, email, phone, etc.) with the following sites during the previous six months (June 1, 1999 - November 30, 1999). Leave the location of your primary office blank." For each site (two in Germany; three in the

US; one in France; and any other place not listed) participants could respond with "Never," "A few times a year," "Once a month," "Once a week," "Once a day," or "More than once a day."

C) While communication in organizations is typically work-related, non-work communication is an important contributor to relationships among team members. Non work-related communication provides opportunities to develop emotional ties among co-workers that can lead to greater openness and sharing (Rocco et al, 2000). Thus, communication is one of the main mechanisms for enhancing trust in an organization (Sally, 1995; March & Simon, 1958). Thus, we asked participants about their social relationships with other team members, in terms of their work and non-work contact patterns (who they contacted), and frequency of work and non-work communication. We also asked questions to determine whether specific media were more conducive for social exchanges than others. We were interested in this question because lack of social interaction may be a force that acts as a barrier to remote collaboration (Olson and Olson, 2000). Specifically, participants were instructed to:

- "Consider your social communication with co-workers on the CAR team. Please choose those people you most often communicate with socially. This list can overlap with the previous list for work-related communication. Selected names will appear automatically in following questions. If the name of a co-worker is not listed, please type in his/her name."
- "How many times per week do you communicate socially... face to face? By phone? By email? By conference calls? By videoconference? By collaborative tools?"

We were also interested in distinguishing between casual social relationships and closer friendships. Previous studies have found strong friendship ties to affect the patterns of organizational change (Krackhardt, 1990), thus we felt that this information might be helpful in understanding possible adoption of technology patterns. Thus we asked:

- "For each co-worker you selected, please indicate your level of friendship with this person."
- Participants saw the heading "Co-workers you communicate with frequently" which indicated the individuals they had already selected, and then they were asked to indicate "I consider this person to be a ...Friend/Acquaintance (select one)."

D) We asked team members to indicate the percentage of their work that fit into each of the following types of workflow: independent, sequential, reciprocal and teamwork. We asked these questions to help assess the collaboration needs of CAR team members at the beginning of the study. Research on computer-mediated communication finds that differences in collaboration tool use can be due in part to the degree of interdependence of co-workers (Walsh et al, 1999). For instance, Walsh et al (1999) found that among scientific researchers, greater interdependence was associated with higher email use. We used Walsh's measure of interdependence (which he characterized primarily as the "reciprocal" work flow in the items below) for our assessment as well. Thus we asked participants to indicate "For your work on the CAR project, please indicate the percentage of your work that fits each of the following descriptions":

- "Independent work, where work and activities are performed by you and your co-workers independently and do not flow between you."

- "Sequential work, where work and activities flow between you and your co-workers in one."
- "Reciprocal work, where work and activities flow between you and your co-workers in a reciprocal "back and forth" manner over a period of time."
- "Team work flow, where you and your co-workers diagnose, problem-solve and collaborate as a group at the same time to deal with the work."

2.5.3. *Outcome measures*

The outcome measures in our study included A) coordination and performance, B) organizational citizenship, C) trust and D) group identification

A) A key issue when studying technology use in business settings is the impact it has on performance and process (Mark, Grudin and Poltrock, 1999). One of the difficulties encountered by researchers is gaining access to measures of team and individual performance. One means to understanding the performance of distributed teams is to assess coordination. For instance, Herbsleb and Grinter (1999) found that difficulties in coordination, such as knowing whom to contact for what, lead to serious problems in team members accomplishing their work. Furthermore, Herbsleb et al (2000) found that the most frequent consequence of cross-site coordination problems was delay in resolving work issues. They explain that work issues that might be resolved quickly in a collocated setting were sometimes delayed by days or weeks as distributed team members tried to establish contact with one another. Thus, we chose to use delay in resolving work issues as a measure of effective coordination in this team, and based these on Herbsleb et al's measure. We also examined other means by which team members sought to coordinate one another, such as their ease in scheduling and finding remote team members. We used these measures to assess the initial level

of coordination difficulties among team members, and expected that coordination difficulties should decrease as a result of collaborative tool introduction. We had participants make these judgments separately for local and distant co-workers in the CAR team, allowing us to analyze whether these outcomes differ for local or remote interactions.

To measure coordination and we asked participants whether they agreed that (on a 7-point Likert scale, anchored by 1 = Strongly disagree and 7 = Strongly agree):

- "People I need to communicate with are difficult to find."
- "It is difficult to schedule common meeting times with my co-workers."
- "My co-workers provide timely information about changes in current plans."

To measure performance we asked participants to indicate:

- "How many times in the past month was your own work delayed because you needed information, discussion, a decision, from someone at your site or another site?"
- "What was the average length of the delays you experienced before acquiring the needed information, having the discussion, or being informed of the decision by the person from your site or the other site?" (Participants could select from 5 categories to answer: Less than an hour, about an hour, several hours, a day, and several days.)

B) In addition to coordination, we chose to consider other indirect measures of performance, such as those directed towards cooperation or helping team members. Katz (1964) first identified the fact that extra-role behaviors, in the form of spontaneous behavior aimed at achieving organizational objectives beyond role specification, are critical to the overall effectiveness of any

organization. The term *organizational citizenship behaviors* was created to depict extra-role behaviors that are discretionary and affect the overall functioning of the organization, such as, actions or suggestions for improving the organization, cooperation with co-workers, creating a favorable environment, and so on (Bolon, 1997; Organ, 1988). In this study, we considered how individuals helped others in their team, as well as how helpful they perceived others to be. We expected that as a result of implementing collaborative tools, organizational citizenship behavior should increase among local and remote members of the distributed team. Thus, we asked participant to indicate the extent to which they agreed, with respect to local and remote co-workers, that (on a 7 - point Likert scale, anchored with strongly agree = 7 and strongly disagree = 1):

- "I pass on new information to my co-workers that I think will be useful to them"
- "My co-workers pass on information that they think might be useful to me"

C) To measure trust we adapted 8 items from Mishra & Mishra's (1994) scale of trust. The scale is based on four dimensions, each of which must be present for mutual trust to exist in a relationship. The dimensions are openness, reliability, caring, and competence. We selected two items from each dimension that best fit the context of the research site. We asked participants to rate local and remote team members separately so that we could compare these responses. Research in this area (Olson and Olson, in press; Herbsleb et al, 2000) indicates that individuals may have lower levels of trust toward remote colleagues. We hoped to find that these levels of trust would rise at the conclusion of the study as a result of our collaborative tool intervention. Each item was on a 7 point Likert scale anchored by 1 = Strongly disagree to 7 = Strongly agree. Participants were

asked to indicate the extent to which "I trust that my fellow CAR team members":

- "Will keep the promises they make."
- "Are competent in performing their jobs."
- "Express their true feelings about important issues."
- "Care about my well-being."
- "Can contribute to the success of our organization."
- "Care about the future of our organization."
- "Have consistent expectations of me."
- Would acknowledge their own mistakes."

D) We asked the extent to which team members agreed with statements that reflected the extent to which local and remote team members viewed themselves to be part of a cohesive team. Group identity indicates the individual perception of belongingness to a group of which the individual is a member. Identification in a group is positively related with collective efforts to reach the group goals, and compliance with shared norms and routines (Rocco, 2000; Tyler 1999). Many empirical and experimental studies indicate that group identity promotes trust even in absence of communication (Kramer & Brewer 1984, Brewer & Kramer, 1986). To measure group identity, we selected two items from Scott's (1997) scale of team social identification. We instructed respondents to:

- "Please think about the CAR project with which you are most involved. In this section, we are interested in your perceptions of how your co-workers feel about being on the CAR project team. For each statement please indicate your level of agreement" for both local and distant co-workers."

- "Team members consider the success of the CAR project team as their success;" (using a 7 - point Likert scale, anchored with Strongly agree = 7 and Strongly disagree = 1).
- We also asked the extent to which they agreed that "Team members view criticism of the CAR project team as a personal insult." (using a 7 - point Likert scale, anchored with Strongly agree = 1 and Strongly disagree = 7).

2.6. Post- intervention questionnaire

The web survey at time 2 (see Appendix J) consisted of 42 questions in 5 sections: technology adoption, communication patterns, coordination, performance and trust.

While the basic format and section of the second survey were the same as the first survey, we made several changes. In general, our motivation was to avoid redundancy and minimize the amount of time required in completing the survey. We received feedback that many respondents spent approximately one hour completing the survey, exceeding the 30 minutes we had expected and promised the research site. In addition, a large proportion of respondents failed to complete the entire survey, skipping questions toward the end of the survey. This led us to believe that the survey was too long and was proving burdensome to complete.

2.6.1. Items eliminated from Survey Time 2

We minimized the length of the survey by eliminating questions regarding the participants' background and workstation, questions regarding non-work relationships and friendship, and group identification. Since we had extensive contact with team members from the first survey and from subsequent tool deployment, we knew that the general characteristics of the team members had

not changed a great deal (age, gender, etc.). In addition, we did not need further information on the team members' workstations, as we had learned that all were equipped with adequate hardware. Furthermore, we no longer needed such information for diagnosis purposes.

We eliminated questions regarding team members' non-work social network for two reasons. First, answering questions about communication patterns were most time-consuming for respondents (see above, for instance, they were required to repeatedly answer multiple questions regarding their communication patterns with up to 15 of their co-workers). By eliminating these questions we could drastically shorten the length of the time required to complete the survey. Second, only 1/3 of respondents chose to answer these questions in the first survey. The fact that participants were reticent to discuss their personal relationships was understandable in an organizational context. As this was a sensitive issue, we believed that it would be in violation of our agreement with the University of Michigan's Institutional Review Board to continue to ask these questions. Furthermore, with such a low response rate, we were unable to use the data from these questions since they did not adequately characterize the team's overall pattern of social relationships.

Finally we removed the group identification questions for three reasons. First, response to these questions was low, as with the non-work related communication questions. Second, responses to these questions did not vary (they were uniformly answered in positive terms), leading us to question the validity of these items for measuring the group members' actual sentiments. Third, we found that the group identification was not related to other outcomes and was not affected by the independent variables in our analyses. Thus, we decided that from a theoretical and practical point of view, it was not worth including these items in the survey a second time.

2.6.2. Items altered in Survey Time 2

In order to reduce the time spent responding to the survey, we altered the questions about communication patterns so that they would no longer require participants to repeatedly answer the same questions regarding up to 15 of their co-workers (as in the first survey). Instead, we asked them to indicate the number of co-workers they communicated with daily about work and non-work related matters. This question is an estimate for the more precise question asked in the first survey.

2.6.3. New items in Survey Time 2

Unlike the first survey where we asked individuals to discuss their motivation to adopt technology, in the second survey we were interested in documenting which tools they had actually used, and how much. At the time of the second survey we had conducted training sessions in Microsoft NetMeeting. However, we realized that team members might have started using other tools of their own initiative. Thus we asked participants to indicate (participants rated their use of these tools on a scale from 1 to 10, with 10 being “regularly” and 1 being “not at all”):

- “How often did you use the following collaborative tools in the last six months?”
- “An electronic calendar like Microsoft Outlook that lets you and your co-workers share information about your schedules on a common calendar?”
- “A presence awareness tool like ICQ that lets you and your co-workers share information about availability?”
- “An application sharing tool like NetMeeting that lets you and your co-workers simultaneously mark up a drawing when you are at your desks?”

In the second survey we also interested in assessing the impact of the collaboration tools that we had implemented during the study. At the time of the second survey we had conducted training sessions in Microsoft NetMeeting. However, we realized that the participants might have used other tools in addition to NetMeeting. Therefore, we asked:

- “Did the use of any of these collaborative tools [mentioned in the previous question] change the manufacturing design process (i.e., the way you and your team went about working on the CAR project)?” Participants were asked to choose “Yes” or “No.” If participants answered "yes", they were asked to respond to the following questions:
- "The use of these collaborative tools improved the *quality* of the product"
- "The use of these collaborative tools improved the *efficiency* of the design process"
- "The use of these collaborative tools improved the *speed* of the design process (each question used a 7 - point Likert scale, anchored with Strongly agree = 1 and Strongly disagree = 7)."

2.6.4. *Items repeated from Survey Time 1.*

The remaining items in the second survey were the same as those in the first survey, except that where appropriate, dates were adjusted to reflect the current time-period. To find the specific questions, refer to Appendix J for the complete survey, or to the following sections above:

- Location items can be found in section 2.5.1 (Background items), part D.
- Items regarding the frequency of work-related communication and travel to other sites can be found in section 2.5.2 (Independent variables), part B.

- Items regarding the frequency of non-work related communication can be found in section 2.5.2 (Independent variables), part C.
- Workflow items can be found in section 2.5.2 (Independent variables), part D.
- Coordination and performance items can be found in section 2.5.3 (Outcome measures), part A.
- Organizational citizenship items can be found in section 2.5.3 (Outcome measures), part B.
- Items regarding trust can be found in section 2.5.3 (Outcome measures), part C.

3. ANALYSIS AND RESULTS

3.1. Time 1 analysis of interview data

3.1.1. *Analysis*

To analyze the interview data, we performed qualitative analyses to determine the most frequently mentioned issues in distributed work within this team. To accomplish this we followed standard practices for qualitative data analysis (Miles and Huberman, 1984; Glaser and Strauss, 1968; 1970). We constructed inductive code categories first by reading through the background interviews and creating an extensive list of all the issues mentioned. We subsequently clustered these into themes of related statements. We used the most frequently mentioned strategic themes to summarize the current practices and barriers in distributed work for this team.

3.1.2. *Results and Discussion*

Baseline evaluation. We generated several themes related to current practice and difficulties in collaborating using the available tools at baseline. We used descriptive statistics from the baseline web survey to support our themes and to aid in recommending collaborative tool interventions in the participant team.

We found that the data fell into three themes: Coordination issues, reliance on email, and maximizing synchronous time.

Coordination issues. Difficulties in remote collaboration are often due to inherent coordination problems of geographically distributed team members, such as large time differences, and managing scheduling and availability effectively. We found this to be true of the participants in our study as well. In particular, team members experienced difficulty due to incompatible time zones and scheduling common work time with remote team members. One participant expressed this problem as follows, saying:

...the very different time zones are the biggest problem [in collaboration]. It is nearly impossible to have all three continents on the phone at the same time. Most (of our) employees are used to the North America – Europe time difference. Australia is more difficult.

In general, respondents described experiencing frustration due to limited synchronous time they shared with co-workers in other time zones, difficulty in coordinating among multiple time zones (such as Europe, US and Australia), and delays in work. On average, team members reported 4 delays each month, with 90% encountering delays of a day or more when working with remote collaborators

Furthermore, team members described difficulty in scheduling common meeting times with both local and remote co-workers. Often, problems in scheduling stemmed from difficulty locating local co-workers who traveled frequently. Yet, problems in locating and scheduling were more pronounced with remote than local co-workers. Coordination issues were strongly correlated with both delays in work and difficulties establishing trust with remote team members (see Tables 2 and 3, Appendix G).

Heavy reliance on email. "The most valuable tool is email... because it's something that's always there."

To overcome the coordination issues inherent in remote collaboration, team members established norms to help them expedite their work. While these norms were resourceful adjustments to dispersed teamwork, they were cumbersome solutions for collaborative work problems.

We found that team members had already developed detailed processes for working with remote team members. Specifically, team members described using email foremost as a tool for contacting remote team members. Email was used as the primary means for exchanging task requests, data, reports, designs and sketches. Often these items were exchanged as attached files.

Yet, these norms fell short of the respondents' needs. Team members encountered difficulties in exchanging email remotely. Travelling team members experienced difficulties remotely accessing their email accounts. Furthermore, participants described file transfer as sometimes slow and causing delays in work. File transfer was especially slow due to large file sizes (often CAD drawings), and because incompatibilities in encryption standards lead to cumbersome security procedures (using ftp, zipped files and passwords).

Finally, email did not offer a rich medium for information exchange. For instance, email did not easily allow users to identify or describe visual details, which are common in design work. As one participant explained:

It is difficult to discuss details over email. Unnamed components must be described to identify them to others, (like the second bow in the tube) since not all parts have names. It's very difficult to discuss this over email because communication is difficult and slow.

Maximizing synchronous time. One of the challenges facing geographically distributed teams is the scarcity of common work times.

Participant team members most commonly used the telephone for synchronous work, while a few team members used shared application tools, and fewer still used video conferencing. Often, team members coordinated synchronous meetings via email. For example, one participant mentioned that one “may say (over email) ‘call me this afternoon, I have to talk to you about such and such.’”

Typically, team members conducted meetings via the telephone in order to discuss coordination issues, plans, acquiring further information or details, and clarifying issues mentioned in email. Team members mentioned that they would like to use visual aids to enhance such meetings. Some team members sent faxes to simply and quickly exchange sketches or other materials. In addition, team members who discussed sketches, designs or other visual material, expressed the desire to have tools to improve mutual understanding of the material (such as being able to simultaneously point to problem areas). For example, one participant described the use of faxes to discuss design work:

Sometimes designers like to sketch first and then send it over, especially when it's to describe something that doesn't work. In theory you could scan the drawing in and make an electronic file, but it's quicker to fax it.

Team members often traveled between North America and Europe in order to facilitate working together. Language differences caused some communication problems that were best handled with face-to-face meetings. Email and telephone interactions were described as working better after there had been an initial face-to-face meeting.

Finally, Americans often used overtime to synchronize work with European counterparts, however the labor laws of one of the European countries involved in the study constrained their citizens to 8 hours work per day.

3.2. Deploying collaboration tools

3.2.1. Tool Implementation

Following the interviews and web survey data collection, we met with representatives of the research site to discuss the baseline data and to formulate subsequent collaborative tool implementation plans. We used the themes generated above to recommend possible means of maximizing their current practices and alleviating collaboration problems. The baseline evaluation suggested that while team members were often using email effectively for asynchronous work, it served as a barrier for synchronous work. For instance, team members described speaking to one another on the telephone, describing a problem and then sending a visual attachment to aid in the discussion. Typically, this would involve interrupting the conversation to wait while the email was sent, received and opened by both parties, sometimes further delayed by server problems. We felt that using an application-sharing tool such as NetMeeting would minimize the delay in synchronous time. One participant described this need as follows:

We would benefit from (shared view). We would be looking at drawings or data on Excel sheets. We're already sending drawings over email (pictures with digital camera of a transmission, or of a drawing, attach JPEG file). We can send it very easily by email, get good quality, and you can draw an arrow on it and say "look at this bow, it in the wrong place." But it's difficult because of delay – you take your thoughts then document it, then send it.

To improve both synchronous and asynchronous coordination, we suggested that awareness tools (such as instant messaging) and calendaring applications would be useful in helping distributed team members find one another and schedule meetings. One participant expressed this need clearly as such:

It would help to know when people are logged into their system, online, because it's hard to find people because of time differences. That way you'd know when to call them (if have presence awareness tools). I had my email set up so it responds when the message is delivered and when people read it. So I get a response back almost immediately, and I know they're at their desk by the phone and I can contact them.

A subset of team members used Microsoft Outlook for calendaring at the time of data collection, and this tool was supported within the company. In addition, participants had described frustration with using the telephone and voicemail as a means of contacting team members. We suggested that a presence awareness tool might help participants target their telephone calls to times they knew their distributed colleagues were available.

Thus, at the conclusion of our meeting, we agreed to implement several collaborative tools in the participating team. These included an application sharing tool (NetMeeting), shared calendar and scheduling, and presence awareness tools.

3.2.2. Application sharing tool deployment and training

In conjunction with the site management team, we identified a subgroup for early adoption of NetMeeting within the participant team, and arranged a schedule of collaborative tool implementation. Members of the subgroup were selected because management believed they had an immediate need to collaborate with remote colleagues. We trained 15 team members in two US and two European locations. The training involved a 15 minute introduction followed by a 30 minute guided use of NetMeeting in a working document sharing session. We coordinated simultaneous training sessions across sites (e.g. US and EU) so that the team members could engage in remote collaboration in the course of their

training. As a follow-up to the NetMeeting training, we sent weekly hints to subgroup members on the use of NetMeeting. In addition, we solicited feedback via email on their weekly use of the collaborative tools.

3.2.3. Shared calendar and scheduling

In addition, we suggested the need for a shared calendar or other scheduling tool to assist team members in locating one another, and hence, to facilitate collaboration. The various tools that could be used for this purpose were discussed with the management team members. An existing calendar package (Microsoft Outlook) was already in place: It had been used in US sites for seven years, but only for a few months in one EU site. In both sites, it was only used sporadically, and usually as a result of a request from top management.

At the meeting we agreed that a shared calendar could help collaboration, that the existing calendar package (Outlook) could be used by all team members for collaboration purposes, that the research site would be responsible for training team members in the use of the electronic calendar and that the research site would examine the legal issues concerning using the calendar in EU. Managers at the research site were hesitant to suggest required use of calendar and scheduling tools to their European employees. They explained that the European Community regulates employee sensitive data and privacy, and the research site believed they would need to get permission from the German Works Council to allow sharing calendar information in its German location. This issue deterred the managers at the research site from pursuing the implementation of the calendar as part of this project.

3.2.4. Presence awareness tools

We also agreed that awareness tools might help with scheduling and spontaneous collaboration and that further research was needed to determine the appropriate awareness tool. We agreed to conduct the background research, and the research site would test the tools behind their firewall. This tool was planned to implemented following the NetMeeting training and deployment. However, at the conclusion of the study, the research site had not expressed an interest in testing or deploying the awareness tools.

3.3. Baseline (Time 1) and Evaluation (Time 2) Survey Findings

3.3.1. Background and Demographic Information (Time 1)

Of the 50 CAR team members, 33 (66%) responded to the baseline survey. Respondents were predominantly white men, of a mean age of 35 years (s.d. = 8.46). They had been at the company a mean of 6.4 years (s.d. = 8.91). Over half the team members responding to the survey (56%) were non-native English speakers, with high average English speaking skills. At the time of the baseline survey, 65% of respondents were located in Europe and 32% were located in offices in the United States (3% chose "other"). Specifically, 53% of respondents' primary office was at the German product development site, 12% at the French site, 26% at the US Division B site, 6% at the US Division A site, and 3% in an other location.

3.3.2. Background information (Time 2)

Summary:

- Approximately the same number of respondents completed each survey.
- Level of overlap in respondents is 1/3.
- Similar proportion of EU and US participants as at Time 1.

34 participants (68% of the team) responded to the evaluation survey (Time 2). Approximately 1/3 of these respondents had completed the baseline survey (Time 1) (for further discussion of the low overlap of respondents from Time 1 and Time 2, refer to section 3.6. "Comparing means at Time 1 and Time 2"). Of these, 70% were located in Europe and 30% were located in offices in the United States. Specifically, 49% of respondents' primary office was at the German product development site, 21% at the French site, 24% at the US Division B site, 3% at the US Division A site, and 3% in an other location. For further information regarding the sample distribution, refer to Table 1, Appendix F.

3.3.3. *Communication Patterns (Time 1)*

We asked about team member's work contact patterns, frequency of communication with other team members across various media, and travel to other sites. On average, participants selected 5.8 (s.d. = 5.39) other co-workers as individuals they communicated with often.

Figures 1.1 and 1.2 indicate the percentage of respondents with high, medium and low frequencies of communication with fellow team members in a typical week, using face to face, telephone and email modes of communication (figure 1.1) and conference call, video conference and collaborative tools (figure 1.2). Overall, the most frequently used mode of communication was face-to-face (83% reported high use), email (35% reported high use) and telephone (29% reported high use). Respondents in Europe and the United States reported differences in media use. Specifically, European team members reported higher levels of telephone and email use than their US counterparts.

Across all modes of communication, respondents contacted the German product development site (where the design work was occurring) most often. 69% of respondents communicated with this German site at least once a week (figure 1.3). Furthermore, respondents visited this site most often, with 13% spending more than 15 days in at the German product development site in the previous six months (figure 1.4).

3.3.4. Communication Patterns (Time 2)

Summary:

- Patterns of media use were similar to those found at Time 1, except that the percentage of participants reporting high frequency of face-to-face communication is lower at Time 2.
- Differences in media use between US and EU persist: EU uses the telephone and collaboration tools more often, whereas US uses more face-to-face communication.
- Collaboration tool use had spread to more than half the team.
- Respondents contacted the same site (German product development site) most often, but traveled to the German manufacturing site most often (unlike Time 1).
- Respondents reported traveling half as often as in Time 1.

We asked about team member's work contact patterns, frequency of communication with other team members across various media, and travel to other sites.

Overall, the mean number of co-workers that participants communicated with at least daily about work related matters was 5.4 (s.d. = 3.86) local co-workers and 2.2 (s.d.= 2.72) distant co-workers. The number of co-workers that individuals communicated with regularly varied a great deal, ranging from 1 to 16 for work-related communication.

Figure 2.1 indicates the percentage of respondents with high, medium and low frequencies of communication with fellow team members in a typical week, using face to face, telephone and email modes of communication and collaborative tools. Overall, the highest frequency of communication was face-to-face (21% reported high use), via email (21.6% reported high use) and telephone (13% reported high use). Collaboration tools had a high frequency of use with 5% of the respondents, whereas 20% of respondents used the tool occasionally, and 65% of respondents claimed to not use collaboration tools at all to for work-related communication.

As in the baseline survey, participants in Europe and the United States reported differences in media use. The telephone continued to be used more frequently by European than American respondents (see Figure 2.2). However, where a greater percentage of European respondents used email frequently in the first survey, the second survey found the frequency of email use to be similar across locations. In contrast, a larger percentage of American respondents communicated face-to-face than Europeans in the second survey. In terms of collaboration tool use, American respondents did not use collaboration tools at all, compared with 42% of European respondents. Half (50%) of the European respondents reported using collaboration tools regularly (between 1 and 4 times per week), and 8% used these tools very frequently. It is possible that the collaboration tool use in Europe may reduce the need for face-to-face communication for European respondents (compared to Americans). In fact, a

post-training interview suggested that European team members often used these tools to hold meetings between office buildings in the same site at the German product development location.

Across all modes of communication, respondents contacted one site most often. 68% of respondents communicated with the German product development location site at least once a week (figure 2.3), approximately the same number as in the first survey. However, unlike the first survey where respondents also visited this site most often, a second site emerged as the most frequent travel destination in the second survey. At Time 2, respondents visited the German manufacturing site most often, with 7% spending more than 15 days at the German manufacturing site in the previous six months (figure 2.4). This change from the first survey likely reflects the downstream production process occurring at time 2. Team members may be visiting this site as they are completing the design process (which occurred most in the German product development site and the US Division B site) and beginning production for a few of their clients.

In general, travel has decreased by almost half since the baseline evaluation. The mean for total number of days spent visiting other sites was 17.71 (s.d. = 27.58) at Time 1, whereas individuals spent about half as much time travelling to other sites at Time 2 (mean of 8.19 days, s.d. = 17.61).

For non-work communication, 73% (N=24) of respondents answered these questions. Of these, participants communicated with a mean of 3.73 (s.d. = 3.48) local co-workers about non-work related matters, and .88 (s.d. = 2.11) distant co-workers about non-work related matters. The number of co-workers that individuals communicated with regularly varied a great deal, ranging from 0 - 10 for non-work related communication. In general, the level of non-work communication reported was low, with higher levels of non-work communication occurring at similar levels across all media (figure 2.5).

3.3.5. *Technology Adoption (Time 1)*

Figure 1.5 indicates the percentages of respondents with high, moderate and low levels of interest in adopting a variety of tools meant to aid collaboration. The overall level of interest in using new technology for collaboration was high. Between 65% and 72% of all team members reported a strong desire to adopt these tools. Nonetheless, European team members consistently reported a lower desire to adopt new technology than their US counterparts. For instance:

- 100% of US respondents reported a strong desire to adopt a shared mark up tool, compared with 55% of European respondents.
- 83% of US respondents reported a strong desire to adopt availability and presence tools, compared with 59% of European respondents.
- 83% of US respondents reported a strong desire to adopt an electronic calendar tool, compared with 55% of European respondents.

3.3.6. *Technology Adoption (Time 2)*

Summary:

- Whereas the technology adoption items in Time 1 assessed the participants' motivation to adopt new tools, the items at Time 2 assessed their actual use of these tools, and the impact it had on their work.
- High calendar use, low application-sharing and presence awareness tool use.
- 50% of respondents agreed that NetMeeting had an impact on their work, with most agreeing that it improved the efficiency and speed of the design process.

Collaboration tool use. Figure 2.6 indicates the percentage of respondents with high, moderate and low levels of use of a variety of tools meant to aid

collaboration, comparing European and American respondents. The overall use of new technology for collaboration was high for some tools and not others. For instance, at the time of the second survey, all (100%, N=34) participants were using the electronic calendar. However, only 38% used a presence awareness tool or an application-sharing tool. Thus, in response to these questions, 62% of respondents indicated that they did not use NetMeeting at all in the last 6 months. This statistic is similar to the one found in response to the question regarding communication frequency, where 65% of participants claimed not to use "collaborative tools" at all. Thus, we must assume that respondents consider presence awareness and application sharing tools to be "collaboration tools," while electronic calendars may fit a broader category of personal and collaborative use. Furthermore, regular use of the shared-application tool was positively correlated with agreement that collaborative tools had changed the design process. Adoption of the other tools (calendar and presence awareness tools) was not significantly correlated with this variable. This corroborates the fact that participants identified NetMeeting as the collaboration tool in question.

Of those who did use application sharing tools at the time of the second survey, 6% of participants indicated that they used an application sharing tool regularly (rated 8, 9 or 10 out of a scale of 1 to 10, where 1 indicates the tool was not used at all, and 10 indicated regular use), and 29% of participants reported moderate use of this tool (ratings of 2 to 7).

In contrast, a high proportion (82%) of participants used a shared calendar tool regularly (rated 8, 9 or 10 out of a scale of 1 to 10, where 1 indicated the tool was not used at all, and 10 indicated regular use). Using the same scale, 12% used a presence awareness tool regularly. These findings were not expected, since no specific intervention had occurred to implement these tools within the team. Furthermore, use of these tools were not significantly correlated with one another,

meaning that an individual's regular use of a NetMeeting had no specific relationship to the calendar or presence awareness tool, and so on.

Impact of collaborative tools. To further interpret the use affect of collaboration tool use, we asked participants whether the use of these tools changed the manufacturing design process, and how the tools had an impact. 50% (N= 32) of respondents reported that the collaboration tools they used had changed the design process. Figure 2.7 illustrates these respondents' opinions regarding the impact on speed, efficiency and quality of the design process.

- 59% agreed that the speed of the design process had improved.
- 82% agreed that the efficiency of the design process had improved.
- 47% agreed that that the quality of the design process had improved

Thus, of those who noticed a change in the design process, most agreed that it was a positive change, and that the tools most affected the efficiency and speed of the design process, with a lesser affect on the quality of the work produced.

3.3.7. *Workflow (Time 1)*

We asked team members to indicate the percentage of their work that fit into each of the following types of workflow:

- Independent: co-workers perform work separately.
- Sequential: work flows between co-workers in one direction.
- Reciprocal: work flows between co-workers in a “back and forth” manner over time.
- Team: co-workers diagnose, problem-solve and collaborate as a group at the same time.
- On average, the greatest mean percentage of the respondents' work was conducted independently (figure 1.6, mean = 30%, s.d. = 22.49).

Furthermore, independent work was negatively correlated with all other kinds of workflow, indicating that the more time spent working independently, the less likely it was that respondents would work in the three other forms.

3.3.8. *Workflow (Time 2)*

Summary:

- On average, the greatest mean percentage (29%, s.d. = 23.42) of the respondents' work was conducted as team work (figure 2.8).
- In contrast, independent work had the highest mean percentage at Time 1.
- In general, team members seemed to be spending more time in reciprocal and team work than independent work (the mean percentage of sequential work has not changed) at the conclusion of the study.

3.3.9. *Working Relationships (Time 1)*

We asked about two types of issues regarding relationships at work: Group identification and trust. Figure 1.7 reports the percentage of CAR team members who agreed, disagreed or were neutral towards statements that reflected the extent to which local and remote team members viewed themselves to be part of a cohesive team. In general, group identification was high. A larger percentage of respondents (96%) believed that criticism of the project was taken as an insult by local, than by remote team members (37%).

Figures 1.8 and 1.9 indicate the percentage of CAR team members who agreed, disagreed or were neutral towards statements reflecting their trust in local and remote co-workers. We found that overall levels of trust in both local and remote team members were high. However, respondents reported consistently lower levels of trust for remote team members than for local team members. These differences were apparent in the statements:

- “I trust that my fellow team members express their true feelings about important issues (96% agreed with respect to local co-workers, whereas 87% agreed with respect to remote co-workers),”
- “I trust that my fellow team members care about my well-being (67% agreed with respect to local co-workers, whereas 52% agreed with respect to remote co-workers),”
- “I trust that my fellow team members have consistent expectations of me (85% agree with respect to local co-workers, whereas 74% agree with respect to remote co-workers),”
- and “I trust that my fellow team members acknowledge their own mistakes (74% agree with respect to local co-workers, whereas 65% agree with respect to remote co-workers).”

3.3.10. *Working Relationships (Time 2)*

Summary:

- Group identification was not measured at Time 2.
- Overall levels of trust were high, as at Time 1.
- As at Time 1, respondents reported lower levels of trust in remote workers on individual items, with some larger discrepancies at Time 2.

In the second survey, we asked about one type of issue regarding relationships at work, trust. Figures 2.9 and 2.10 indicate the percentage of CAR team members who agreed, disagreed or were neutral towards statements reflecting their trust in local and remote co-workers. Again, we found that overall levels of trust in both local and remote team members were high, with mean scores of 5.6 (s.d. = .77) and 5.4 (s.d. = .92) on a scale of 1 (strongly disagree) to 7 (strongly agree) respectively. These means are almost identical to the mean

levels of trust found at the time of the first survey (5.7, s.d. = .73, for local co-workers and 5.5, s.d. = .84, for remote co-workers). Consistent with the first survey, respondents reported slightly lower levels of trust for remote team members than for local team members. These differences were apparent in the statements:

- "I trust that my fellow team members will keep promises that they make (97% agreed with respect to local co-workers, whereas 63% agreed with respect to remote co-workers).
- "I trust that my fellow team members express their true feelings about important issues (87% agreed with respect to local co-workers, whereas 60% agreed with respect to remote co-workers)," and
- "I trust that my fellow team members have consistent expectations of me (89% agreed with respect to local co-workers, whereas 79% agreed with respect to remote co-workers)."

However, it is notable that while trust in remote co-workers was lower on individual items at the time of this first survey, the disparity in levels of trust on individual items appears to be greater at the time of the second survey. For instance, at the time of the first survey, most (over 90%) of participants agreed that local and remote co-workers keep promises they make (less than a 5% difference between perceptions of local and remote co-workers. Yet, at the time of the second survey the disparity between the belief that local and remote co-workers keep promises has grown to 34%. For the two other statements mentioned above, the difference between perceptions of local and remote co-workers was 9%. In contrast, there is a 27% difference in the number of participants who believe that their local and remote co-workers express their true feelings. Thus, while overall levels of trust seem to have remained the same from

the beginning of the study, it seems that the disparity between trust in local and remote co-workers might have increased in some ways at the conclusion of the study.

3.3.11. Coordination, performance and organizational citizenship (Time 1)

Respondents reported greater difficulty in coordinating their work with remote than local coworkers (figure 1.11). For instance:

- 18% agreed that it was difficult to schedule common meeting times with local co-workers, compared to 48% with remote co-workers.
- 24% agreed that local co-workers they need to communicate with were difficult to find compared to 38% for remote co-workers.

Furthermore, there was a positive correlation between receiving timely information about changes in current plans from remote co-workers, and reported trust in remote co-workers.

Team members indicated experiencing delays in work involving both local and remote co-workers (figure 1.13). It is interesting to note that a greater number of respondents (50%) reported a high frequency of delays (four or more delays in the previous month) involving local co-workers than with remote co-workers (42%). In contrast, most respondents (90%) reported a high average length of delay (one to several days delay) in work involving remote co-workers, whereas less than half (48%) reported such lengthy delays with local co-workers. Difficulty scheduling common meeting times with remote co-workers was positively correlated with frequency and average length delays involving remote co-workers.

In general, respondents reported high levels of organizational citizenship (figure 1.10). Yet, a lower percentage agreed that they passed on useful information to remote (84%) than local (89%) co-workers. In addition, a lower

percentage of respondents reported that their remote co-workers passed such information on to them than local co-workers (62% and 79% respectively).

3.3.12. Coordination, performance and organizational citizenship

Summary:

- As at Time 1, participants continue to have greater scheduling difficulties with remote than local co-workers.
- A high frequency of delays was more common with local remote co-workers, as at Time 1.
- The number of high frequency delays decreased at Time 2.
- High length of delay was more common with remote than local co-workers, as at Time 1.
- Mean length of delay has decreased.
- Time 2 organizational citizenship levels slightly higher than at Time 1.

Figure 2.11 indicates the percentage of participants who agreed, disagreed or were neutral to statements reflecting difficulties in scheduling, locating and receiving information from local and remote co-workers. At the time of the first survey, respondents reported greater difficulty in coordinating their work with remote than local co-workers. This trend continued at the time of the second survey, with a slight decrease in difficulties scheduling and locating remote team members at the time of the second survey. For instance:

- 17% agreed that it was difficult to schedule common meeting times with local co-workers, compared to 40% with remote co-workers.
- 23% agreed that local co-workers they need to communicate with were difficult to find compared to 28% for remote co-workers.

- A greater percentage of participants agreed that they received timely information about changes in plans from local than remote participants (63% and 40% respectively) which is an increase since the time of the first survey (54% and 28%).

It is possible that these improvements in coordinating with local and remote co-workers were related to the increased maturity of the team, since as team members get to know one another, they may have better knowledge of their local and remote co-workers' schedules and norms for availability. However, it is also likely that team members are benefiting from increased calendar use (noted in the technology adoption section) within the team. While our intervention did not include the implementation of an electronic calendar, interview data at the conclusion of the study indicated that use of the calendar package MS Outlook had spread informally, without any specific interventions from management.

Participants indicated experiencing delays in work involving both local and remote co-workers (figure 2.12). A greater number of respondents (41%) reported a high frequency of delays (four or more delays in the previous month) involving local co-workers than with remote co-workers (36%). This pattern was identical to the one observed in the evaluation survey (Time 1). In addition, the percentage of respondents reporting high frequency delays decreased for both local (by 9%) and remote (by 6%) co-workers.

In contrast, most respondents (95%) reported a high average length of delay (one to several days delay) in work involving remote co-workers, whereas 1/3 fewer participant (61%) reported such lengthy delays with local co-workers. This pattern is also similar to the one identified in the first survey. One notable change is that while the number of participants who encountered lengthy delays with remote co-workers remained constant, the number of participants reporting lengthy delays with local co-workers has increased. However, the overall

average number of delays (for both local and remote co-workers) has decreased slightly (though not statistically significantly) from 2.65 (s.d.= 1.34) for local co-workers at Time 1 to 2.39 (s.d. = 1.34) at Time 2, and from 1.80 (s.d. = 1.20) for remote co-workers at Time 1 to 1.41 (s.d. = .59) at Time 2. These correspond to about one day's delay with local co-workers and several days with remote co-workers.

In general, respondents reported high levels of organizational citizenship (figure 2.14). Yet, a lower percentage agreed that they passed on useful information to remote (88%) than local (97%) co-workers. In addition, a lower percentage of respondents reported that their remote co-workers passed such information on to them than local co-workers (72% and 83% respectively). In general though, individuals who passed on information to local co-workers were more likely to pass information on to remote co-workers (significantly correlated at $p < .01$), and individuals who received information from local co-workers were also likely to receive information from remote co-workers (significantly correlated at $p < .01$). In addition, individuals who passed information on to remote co-workers also reported greater levels of receiving information from local and remote co-workers. These trends are similar to those found in the baseline survey (Time 1), except that levels of organizational citizenship have increased slightly over time for both local and remote co-workers.

3.4. Comparing means at Time 1 and Time 2

We examined the difference in mean scores on outcome variables from the baseline survey (Time 1) to the evaluation survey (Time 2). We analyzed the difference in means using a paired-samples t-test. This is the standard statistic

used to compare before and after measures on the same sample. We believe this is the appropriate test to use to compare identical measures in both surveys.

We found only one significant difference among the variables we considered. Only the mean percentage of time spent in independent work changed significantly ($p < .01$), from 32.5% at Time 1 (s.d. = 22.49) to 21.25% (s.d. = 20.71) at Time 2. The other variables, while displaying notable differences in means, were not statistically significant. These findings are listed in Tables 8 and 9, in Appendix I.

One reason why these findings may not be completely accurate in describing changes from baseline to evaluation is due to the nature of the statistical test. The paired-samples t-test eliminates data from participants who did not respond in both Time 1 and Time 2 for each variable in question. As a result, we found that the sample size was often reduced to 1/3 of the participants who completed the survey both times (to determine the sample size for each item in Table 8, add 1 to the degrees of freedom or d.f.). The smaller the sample size, the greater an effect must be in order to be determined as statistically significant. Thus, differences in means which may seem large (like 17.92 total number of days spent visiting other sites at Time 1 compared with 12.25 at Time 2), are not statistically significant.

Furthermore, the means displayed in the table represent only that data collected from the subgroup of participants who completed the item both times. Thus, the means for total number of days spent visiting other sites are actually 17.75 at Time 1 (approximately the same) and 8.19 at Time 2 (much lower than the subgroup's mean of 12.25). Thus, we must use caution in interpreting the results from the paired-samples t-test.

3.5. Relationships among variables

We used correlation analysis to determine whether variables were associated with one another. All the correlation results listed in the following section are significant at $p < .05$ or greater unless stated otherwise. Correlation tables of the dependent variables with one another is available in Appendix H.

3.5.1. Impact of collaboration tools

Summary:

- Speed, efficiency and quality improvements related to one another
- Application-sharing tool adoption related to impression of impact of NetMeeting on work.
- Communicating with more co-workers related to perceiving impact of NetMeeting on work.

NetMeeting impact. We found that participants' impressions of the impact of NetMeeting on different dimensions were associated with one another. For instance, quality and efficiency improvements due to the collaborative tool intervention were positively correlated with one another, as were efficiency and speed improvements. This leads us to believe that the impact of NetMeeting may be described as a general improvement as well as characterized on a more specific basis.

Technology adoption. Adopting NetMeeting was positively correlated with agreement that NetMeeting had changed the design process. Adoption of the other tools (calendar and presence awareness tools) were not correlated with this variable. This corroborates the fact that participants identified NetMeeting as the collaboration tool in question.

Tools and communication. We found a positive correlation between the number of local and remote co-workers that participants communicated with daily, and perceiving a change in the design work as a result of the implementation of NetMeeting. Thus, the greater the number of team members one communicated with daily, the more likely one is to have perceived an impact on design work as a result of tool implementation

3.5.2. *Coordination*

Summary:

- Coordination problems related to one another.
- Number of co-workers one communicates with related to receiving timely information.
- Receiving timely information related to perception of improvements in work due to NetMeeting.
- Coordination difficulties associated with decreased organizational citizenship.

Coordination. We found that difficulties in one type of coordination were associated with difficulties in other areas as well. For instance, local and remote scheduling difficulties were positively correlated (these items were coded in reverse, such that higher scores indicate less difficulty scheduling), as were receiving timely information about changes in plans from local and remote co-workers, and difficulty finding local and remote co-workers. In addition, difficulties scheduling meetings with local co-workers were positively correlated with difficulty receiving timely information from remote co-workers. Thus, individuals who perceived scheduling difficulties with local co-workers also perceived greater difficulty in receiving information from remote co-workers.

It is interesting to note that difficulty in scheduling meetings with remote co-workers was not related to any other dependent variables. It is possible that team members recognize the barriers in coordinating with remote co-workers (also evident from our interview data), and thus may give remote co-workers greater leeway in scheduling meetings.

Coordination, communication and NetMeeting. We found a positive correlation between the number of local co-workers one communicated with and receiving timely information from local co-workers. Thus, communicating with a larger number of local co-workers was associated with receiving more timely information from them. It is possible that one's position in the organizational hierarchy may confound this association, since those more senior team members with greater responsibility (managers, etc.) are more likely to communicate for work-related purposes with a larger number of employees than novice engineers, for instance.

Perceptions of efficiency and speed improvements in the design process as a result of the NetMeeting intervention were positively correlated with the perception that remote co-workers provided timely information regarding changes in plans. This finding supports the notion that NetMeeting was valuable in working with remote co-workers. It is possible that the use of NetMeeting reduced time spent sending documents to one another and followed by later discussion of the visual documents. For instance, in key informant interviews, team members described speaking to one another on the telephone, describing a problem and then sending a visual attachment to aid in the discussion, which would involve interrupting the conversation to wait while the email was sent, received and opened by both parties. It is possible that NetMeeting improved the flow of information between remote co-workers.

We found a correlation approaching significance ($p < .10$) between regular calendar use and difficulty finding remote co-workers. That is, more regular use of the calendar was associated with less difficulty locating remote team members. However, regular use of the calendar was also significantly associated with receiving less timely information from remote co-workers. The calendar tool was aimed at increasing coordination, thus, the finding that it is useful in locating team members is encouraging. It is more difficult to interpret the finding that the calendar was associated with receiving less timely information. In fact, while an electronic calendar can indicate when co-workers are unavailable (due to vacation, travel, meetings, etc.), they are not helpful in determining when an individual will actually respond to a request. Perhaps this finding indicates the greater frustration associated with knowing another person's schedule and still waiting for a response from them.

Coordination and organizational citizenship. It seems that coordination issues have an impact on extra-role behavior of team members. In fact, lower levels of coordination problems were associated with both individual citizenship behavior, and perceptions of other's citizenship behavior. For instance:

- Difficulty scheduling meetings with local co-workers were positively correlated with passing on information to remote co-workers. Thus, perceiving fewer difficulties in scheduling with local co-workers was correlated with passing on useful information to remote co-workers. It was also positively correlated with receiving information from local and remote co-workers, indicating that as individuals perceived fewer barriers to coordinating with local co-workers, they tended to perceive greater organizational citizenship from their team members.

- Receiving timely information about changes in plans from local co-workers was positively correlated with perceptions that local co-workers pass on information they think might be useful.
- Ease in locating local and remote co-workers was positively correlated with perceptions of organizational citizenship behavior of remote co-workers.

3.5.3. *Performance*

Summary:

- Length and frequency of delay related to one another.
- Frequency of face-to-face communication related to less delay from remote co-workers.
- Coordination difficulties related to performance problems.
- No correlation between NetMeeting use or perceived impact and performance.

Performance. Our measures of performance were correlated with one another. For instance, frequency of delays due to local and remote co-workers were positively correlated with one another, as were average length of delay due to local and remote co-workers. In addition, frequency of delays due to local co-workers was negatively correlated with length of delay due to local co-workers, meaning that greater numbers of delays were associated with greater average length of delays. Thus, experiencing delays in work may be a more general phenomenon, such that certain team members may be more likely to experience frequent, long delays with both local and remote co-workers, while others experience few delays, which are of shorter duration.

Performance and communication. We found a positive correlation between frequency of local face-to-face work-related communication and average length of delay due to remote co-workers. This means that greater incidence of

face-to-face work with local co-workers is associated with shorter delays in work caused by remote co-workers.

Performance and coordination. Difficulties in coordinating with team members were related to performance issues on many levels. For instance:

- Difficulty locating local and remote co-workers was positively correlated with length of delay. Thus, the greater ease one had in locating co-workers, the shorter the average length of delay perceived by participants, due to remote co-workers.
- Difficulties scheduling meetings with local co-workers were positively correlated with length of delay due to local co-workers. Thus, increased local coordination was associated with shorter delays in obtaining work input from local team members.
- Receiving timely information about changes in plans from local and remote co-workers was positively correlated with reduced length of delay with local co-workers. This means that the more participants rated local co-workers as giving them timely information, the shorter the average delays they experienced as a result of local co-workers. Receiving timely information about changes in plans from remote co-workers was also associated with decreased delays from remote co-workers.

Therefore, it is possible (as we surmised at Time 1), that alleviating coordination problems may contribute to improving performance (reducing number and length of delays in work). In examining the relationship between collaboration tool use and coordination, and collaboration tool use and performance, we can better test this assumption.

However, we found only partial support for the relationship between collaboration tool use and improvements in coordination. For instance, regular use of NetMeeting was not significantly correlated with coordination (thus, we

can establish no specific relationship between the two). Of those team members who perceived that the design process had been changed by the use NetMeeting, coordination improvement (more timely information form remote co-workers) was associated with perceptions of efficiency and speed improvements in the design process as a result of NetMeeting. These findings suggest that the link between NetMeeting use (the deployment, support, usability, spread of use, and so on) and coordination improvements is weak, and deserves further investigation.

Performance and NetMeeting use. It is also possible that while coordination and performance are closely linked, that NetMeeting use may affect performance directly. However, we found no significant correlation between collaboration tool use and improvements in performance.

We found mixed results for depicting the relationship between the perceived impact of NetMeeting on the design process and performance. For instance:

- Agreement that NetMeeting had improved the efficiency of the design process was negatively correlated with frequency of delay due to remote co-workers. Thus, greater perceptions of improved efficiency due to the NetMeeting were associated with lower number of delays caused by remote co-workers.
- Yet, indicating that NetMeeting had affected the design process was correlated with higher frequency of delays due to remote co-workers. Furthermore, agreement that NetMeeting improved the quality of the design process was associated with increased length of delay due to local co-workers.

The relationship between collaboration tool use and performance is not clear. There appears to be no specific relationship between use of the tool we deployed, or those spontaneously implemented in the team (calendar and presence tools), and improved performance in the team. Furthermore, the relationship

between perceived impact of the collaboration tools and performance is mixed (positive and negative).

3.5.4. *Trust*

Summary:

- Trust items related to one another.
- No specific relationship between NetMeeting use and trust.
- Perceptions of improved speed of work due to NetMeeting related to increased trust.
- Negative relationship between calendar use and trust.
- Ease of coordination related to increase in trust.
- Performance problems associated with decrease in trust.
- Increased organizational citizenship related to increase in trust.

Trust. We found that levels of trust in local and remote co-workers were correlated with one another. This suggests that while qualitative differences exist between perceptions of trust in local and remote co-workers (described above), individuals tend to rate both sets of co-workers in the same direction. Thus, higher levels of trust in local co-workers were associated with higher levels of trust in remote co-workers (though these may be slightly lower for remote co-workers).

Trust and NetMeeting. One of our research objectives was to determine the relationship between collaboration tool use and trust. We expected that trust might be improved as distributed team members have opportunities to establish common ground and overcome spatial and cultural barriers by using an application-sharing tool such as NetMeeting. However, we found no specific relationship between the use of NetMeeting and trust. Nonetheless, we found that

perceptions that the use of NetMeeting improved the speed of the design process were positively correlated with increased trust in remote co-workers, and overall increased trust (but not in local co-workers alone).

It is interesting that we found a negative correlation between regularly using the electronic calendar and trust in remote co-workers. Thus, perhaps simply using the calendar oneself may not yield any positive benefits -- however, if the individuals one is targeting also use the calendar, one may experience greater ease in coordination (which is correlated with increased trust).

Trust and coordination. We found that coordination issues and trust were related on several levels. For instance:

- Greater ease in locating distant co-workers was associated with greater trust in local and remote (and overall) team members.
- Receiving timely information about changes in plans from local and remote co-workers was positively correlated with increased trust in local and remote co-workers. Receiving timely information about changes in plans from remote co-workers was also associated with increased trust overall.
- Difficulties scheduling meetings with local co-workers (reverse coded) were positively correlated with trust (overall, local and remote). Thus, increased trust in all team members was related to less difficulty in coordinating with local team members.

Trust and performance. We found evidence of a positive relationship between performance and trust, in that:

- Length of delay due to local co-workers was positively associated with trust in local co-workers, thus lower average length of delays were associated with increased levels of trust in local co-workers.

- Length of delay due to remote co-workers was positively associated with trust in local and remote co-workers (and overall) thus lower average length of delays were associated with increased levels of trust in general.
- Greater frequency of delays due to local co-workers were negatively correlated with trust overall and trust in local co-workers. Thus, increased delays due to local co-workers were associated with lower levels of trust in local co-workers and overall.

Trust and organizational citizenship. We found that reporting organizational citizenship behavior was positively related with trust. For instance:

- Receiving useful information from local and remote co-workers was positively correlated with local, remote and overall trust.
- Passing useful information on to remote co-workers was positively correlated to distant and overall trust.

These findings support the assumptions we have made about the importance of being able to coordinate with and rely on team members in order to build and maintain trust in the team. This was consistent across both the baseline and evaluation surveys. Thus, understanding how collaboration tools play a role in affecting the coordination-performance-trust triangle remains a question worthy of investigation.

It is more difficult to assess the exact relationship of collaboration tool use and trust. While there was no specific relationship between NetMeeting use and trust, the belief that collaboration tools improved the speed of common work was related to increased trust.

4. DISCUSSION

As we stated in the introduction, our motivation in conducting this study was to understand the impact of network-based collaborative tools on the performance of geographically distributed work teams. The significance of this research area is highlighted by the growing globalization of work, which requires an increase in coordinated activity across dispersed sites and employees. Specifically, in the manufacturing sector, it is becoming common practice for engineers from different backgrounds and at different locations to combine their efforts to produce novel products. Similarly, customers are coming to expect that modern communication technologies will allow faster response from manufacturers, which in turn increases pressure on manufacturers to improve mechanisms for communication and collaboration with suppliers. Our strategy to assess the effects of these macro-scale changes was a detailed examination of a representative geographically dispersed engineering team.

With the cooperation of our industrial partner, Auto 1, we were successful in identifying a product development group that spanned three continents and two divisions of the company. The CAR team modeled, on a small scale, key issues that we believe are universal characteristics of multi-site engineering projects. First, the engineers were located all over the world and regularly confronted barriers of distance and time. Second, the members of the team had to cope with cultural, linguistic, procedural, and technological differences – often with little allowance or guidance from the organization – while also performing the regular components of their jobs. Third, the infrastructure to support the work of the team was dynamic, particularly the underlying network technologies, which required ongoing adjustment and accommodation by the engineers. Fourth, the team brought together engineers with diverse technical backgrounds, which imposed demands to express problems and solutions via mutually understandable

terms and concepts. Fifth, the team was under extreme pressure to meet scheduled deliverables – with key milestones under constant negotiation with prospective customers. Sixth, the success of the team had strategic importance, since the potential market was estimated at over \$1 billion. Seventh, the team was newly assembled to produce the target automotive subsystem and did not have a prior history of working together. And finally, the team was the initial effort by the larger organization to join expertise across corporate divisions in order to develop an innovative product.

Against this background of a representative geographically distributed engineering team, we designed a collaboration technology deployment strategy based on rigorous analysis of the team's requirements, and then instrumented the deployment to assess the impact of collaboration technology use on the team's effectiveness. Our requirements effort recommended three technology interventions: a tool for synchronous viewing of engineering drawings and documents (e.g., Microsoft NetMeeting); a tool for shared calendars (e.g., Microsoft Outlook); and a tool for presence awareness (e.g., ICQ). Due to resource constraints within Auto 1, and legal concerns with the export of personal data – like schedule information – outside the European Union, we were only able to pursue one direct intervention: a supported introduction of NetMeeting. However, based largely on our feedback, the CAR managers launched an independent effort to encourage shared calendar use. In addition, there was some spontaneous adoption of presence awareness tools. Therefore, through a variety of mechanisms, the CAR team did experience a significant increase in use of collaborative tools over the period of the study, and that use led to a number of critical insights. These insights can be categorized in terms of contributions to our understanding about: a) the general role of collaborative tools in geographically distributed teams, and the specific impact on geographically

distributed manufacturing engineering teams; b) techniques and methods for assessment and evaluation of technology-related changes, particularly related to the introduction and adoption of collaborative tools; and c) practical recommendations to organizational leaders, in the manufacturing sector and more broadly, about how and when to introduce collaborative tools to ensure maximum success.

4.1. The role of collaborative tools

We were most interested in levels of adoption and use of the recommended collaborative tools, and the relationship between collaboration tool use and any changes in team performance and effectiveness, based on comparison of pre- and post-intervention measures. Specifically, we hoped to find a positive impact of tool use. To place this effort in context with respect to our main tool intervention with NetMeeting, there are only two published studies on NetMeeting in the literature (Mark, Grudin, & Poltrock, 1999; Finholt, Rocco, Bree, Jain, & Herbsleb, 1998). In the case of Mark et al. (1999), the study focused on room-to-room use of NetMeeting in an engineering design setting within an aerospace manufacturing organization, primarily as an adjunct to audio conferences. Data were gathered on four teams over a period of three months. In the case of Finholt et al. (1998), the study focused on targeted dyads of remote users doing software engineering within a telecommunications organization, again, covering a period of three months.

4.1.1. Adoption and use of collaborative tools

We concentrated NetMeeting training on fifteen members of the CAR team judged, by their management, to have the greatest need for NetMeeting features. This strategy succeeded in exposing NetMeeting to a significant fraction

of the CAR engineers. For example, from a baseline level of no use, 36% of the CAR team reported some level of NetMeeting use by the end of the study period – but all users were at European sites [Note: We are aware of regular use at US sites – but these engineers did not respond to the second wave survey.] A small number of team members, 6%, reported regular use of NetMeeting. In terms of the other two recommended collaborative tools, shared calendars and presence awareness applications, there was a less formal deployment effort (e.g., no training or support). By the end of the study, 97% of the CAR team reported some level of shared calendar use – and a large number of team members, 82%, reported regular shared calendar use. Adoption of presence awareness tools was much lower, with some reported use by the end of the study among 36% of the CAR team. A small number of team members, 12%, reported regular use of presence awareness tools.

An unresolved question is why adoption of the calendar tool was so much broader than the adoption of NetMeeting and presence awareness tools. A key factor is that in response to our summary of baseline and requirements data, the lead managers within the CAR team made a decision to recommend use of the shared calendar tool. However, NetMeeting was also strongly endorsed by management. We believe an additional factor in the differential adoption rates was that the number of engineers who benefited from the relatively specialized capabilities of NetMeeting or presence awareness tools was much smaller than the number who benefited from the relatively generic capabilities of the shared calendar tool. That is, scheduling is a more universal need. By contrast, a tool for application sharing or presence awareness at a distance appeals mainly to those workers who must collaborate with distant colleagues and must do so in real-time, as when viewing a common drawing or document. For instance, one US engineer conducted regular intensive collaborative work with a colleague in a European

site that required rapid feedback. During the period after the NetMeeting training, this individual reported weekly meetings using NetMeeting – and that these meetings were critical in the resolution of key design problems. Finally, the manager of the Division B element of the CAR team observed that most of their work with EU colleagues was concentrated on the French manufacturing site – and not the German product development site. At the time of the study, the French site had very poor network connectivity. As a result, NetMeeting use might have been less than team members desired reflecting the low performance of the network links between the US and the French location. Specifically, in both the interview and first wave survey responses, US-based engineers indicated enthusiasm for a tool like NetMeeting that would allow application sharing at a distance (e.g., 100% of US respondents reported a strong desire for an application sharing tool).

4.1.2. Impact of collaborative tools

We asked team members about the collective impact of collaboration tool use on changes in the manufacturing design process. Looking at the whole team, 50% felt that changes had occurred. However, focusing on those team members who used the various tools, the numbers were different. For example, among NetMeeting users 66% reported change compared to 37% among non-users – while only 46% of calendar and 45% of presence awareness users reported change. Looking at those who reported changes, 56% of NetMeeting users felt that efficiency and speed had improved, although only 22% felt that quality had improved. Among shared calendar users, 83% felt that efficiency had improved, 75% felt that speed had improved, and 50% felt that quality had improved. Finally, among presence awareness users, 80% felt that efficiency had improved, 60% felt that speed had improved, and 60% felt that quality had improved. These

results suggest two conclusions. First, that NetMeeting use produced a more profound perception of change than either shared calendar or presence awareness use. Second, when changes were reported, the primary impact across all collaboration tool use was on efficiency and speed, with a smaller impact on quality. Specifically, perceptions of efficiency and speed improvements were positively correlated with the perception that distant co-workers provided timely information. This relationship suggests that use of collaborative tools did reduce some of the difficulties indicated in the initial round of interviews, such as interruptions in mid-conversation to email attachments with drawings.

We also asked team members about critical performance outcomes, such as the frequency and duration of delays. We analyzed these measures with respect to collaboration tool use and did not find any specific relationships. Further, we asked team members about critical process issues, like frequency of travel. While frequency of travel did decline according to responses at the second survey administration, there was no significant association of this decline with use of the introduced collaboration tools. The Division B manager, when questioned about the reduced travel, attributed the reduction to the natural ebb and flow of travel corresponding with different periods of the manufacturing design cycle. That is, in his opinion, higher travel at the time of the first survey administration probably reflected a more intensive overall level of interaction between the European and U.S. sites than at the time of the second survey.

Finally, we asked team members about critical social and psychological factors, such as trust. We expected, for example, that trust might be improved as distributed team members increased opportunities to establish common ground and overcome spatial and cultural barriers by using collaborative tools. However, we found no specific relationship between the use of collaborative tools and trust. We did find that a factor associated with collaboration tool use, perception of

improved speed, was positively related to trust in remote co-workers, and overall increased trust (but not in local co-workers alone). This suggests that greater responsiveness plays a role in assessments of trustworthiness, and to the extent that collaborative tools improve responsiveness, they may be expected to influence perceptions of trustworthiness.

4.2. Techniques for assessment and evaluation

The main focus of this research was characterization of the use and impact of collaborative tools within a representative distributed engineering team. However, a critical secondary goal was demonstration of techniques for assessment and evaluation of collaboration tool interventions that could be generalized to other field settings. In this section, then, we present a summary of the strengths and weaknesses of the research strategy implemented in this study.

Over the course of our one year project at Auto 1 we made dozens of visits to CAR team sites, including two trips to European locations. We organized three “all hands” meetings involving Auto 1 upper management, CAR team management, the Auto 1 IT organizations, and UM and NIST researchers. We developed, administered, and analyzed two surveys. Finally, we developed and implemented a complete technology deployment, including one-to-one training, and tracked the consequences of the deployment for six months. These efforts were conducted against a backdrop of: a) uncertainty with respect to the ultimate success of the CAR team’s product; b) uncertainty concerning the legal relationship between Auto 1 and the University of Michigan concerning the overall research project, particularly with respect to intellectual property; and c) the departure, halfway through the research period, of the Auto 1 vice president who invited and nurtured our project.

Our difficulties in conducting the research reflect the first crucial lesson, in terms of the assessment and evaluation strategy. Doing research in the field, within actual engineering teams, requires enormous cooperation and compromise. For example, we wanted to introduce three collaborative tools – but because of Auto 1 legal and operational concerns – were only allowed to introduce NetMeeting (although shared calendars were introduced, apparently unilaterally, by the CAR team management).

Second, having negotiated access to Auto 1 on the basis of minimizing demands placed on the Auto 1 IT organizations, we were placed in the position of conducting the bulk of training and also debugging problems with applications, such as NetMeeting server failures. This meant that tremendous effort was expended just to bring a critical mass of users to a minimum level of competency with the target collaborative tools – effort that under other circumstances might have gone directly to observation of the tools in use or to enhancing practices with the tools.

Third, the surveys had the advantage of gathering data broadly at relatively low cost, at least in terms of administration. However, the response rates – and particularly the low overlap in response between the two waves of the survey – reduced our capacity to draw useful conclusions. For example, the second wave survey showed no US-based NetMeeting users, yet our interview and site visit experience suggested that there were some regular NetMeeting users at the US locations.

Fourth, we learned that overcoming inertia in organizational settings is very difficult. In other words, if a solution to collaboration issues already existed, there was little incentive for participants to change to another solution. This was true for NetMeeting use. Frequent users of email attachments found NM to be a

benefit to them, but those who less frequent attachment users did not seem to want to use NetMeeting. As one participant put it:

In our case, we find e-mails with attached files, having access to common data bases and utilisation of Acrobat to be our most useful tools.

Similarly, another subgroup used application sharing – but not via NetMeeting (they used PC Anywhere). The leader of the group explained that:

We're using PC Anywhere to call in over VPN with an IP address... We have software installed on a host computer set up in US, and I can call that software, it's CAD packages, and so we can do a virtual design review. And its been working quite well, its reasonably fast.

Since this multi-purpose solution was adequate for him, he did not find it necessary to put in the effort to change applications (this was communicated in a follow-up interview). This was true even though this person was perceived by management to be technology-savvy and an early adopter of technology in general. Learning the new tool was not a problem, but there was little incentive for him to change.

Fifth, our entrée to Auto 1 and early development of the project was greatly facilitated by the enthusiastic support of the VP for Human Resources in Division B – who approached us to volunteer Auto 1 as a research site. This VP played an essential role in helping us negotiate across the two divisions involved with the CAR project. The significance of this guidance reinforces the importance, particularly in field research, of a high-level champion within the field organization. Momentum on this project slowed considerably when our high-level champion left Auto 1.

Finally, our status as outsiders allowed us to probe the CAR team members to reveal practices and procedures that the engineers themselves, and Auto 1 personnel, did not have the time or inclination to explore. However, as

outsiders, we confronted a very steep learning curve to understand the content of the engineering work. Again, effort expended on mastering the elementary aspects of the engineers' tasks could have been allocated to more detailed examination of performance of the tasks – and the relationship between these tasks and collaborative tools. In this way, inclusion of a veteran automotive engineer, specifically one from Auto 1, on the research team might have accelerated understanding of what the CAR team was trying to do. Yet, in the time and resource starved environment where CAR team members worked, it was unlikely that CAR team management or Auto 1 would have consented to a worker acting in a formal liaison role.

4.3. Practical recommendations

We believe the CAR team was representative of the universal difficulties and challenges confronted by multi-site engineering organizations. However, it was a single team within one organization, so any generalizations should be made with appropriate caution. Specifically, unique features of this research setting included the history of very autonomous divisions within Auto 1 – which may have created higher than normal difficulties in cross-division communication and cooperation. Also, the strategic importance of the CAR project, and the corresponding high visibility within Auto 1, may have increased motivation to perform, such that the addition of collaborative tools had less impact than would be the case in a more typical team. Finally, because of the cross-cultural interaction within the CAR team, multi-site collaboration issues might have been confounded with cultural and language issues. However, in recognition of this potential problem we did probe for culture and language-specific issues and found that most workers, for example, spoke and understood English very well.

With these caveats in mind, there are a number of practical recommendations that we can make based on the CAR team's experience. These recommendations fall into two categories: a) advice to managers and engineers about adoption and use of collaborative tools; and b) advice for future researchers studying the impact of collaborative tools in engineering settings.

4.3.2 Advice to managers and engineers

The foremost conclusion of this study is that collaborative tools must meet a specific need to merit the effort of deployment, adoption, and subsequent use. For example, the requirements gathering effort conducted early in this project successfully highlighted difficulties, or constraints, experienced by the CAR team members when attempting to do cross-site work. At least for some of the CAR engineers, as indicated by adoption and use rates, the set of introduced collaborative tools met the identified needs. Yet, for many, the available tools still imposed too great a burden to learn and master, relative to the perceived benefits. That is, for those who interacted heavily with colleagues at distant sites the collaborative tools we introduced were well received. But for others, existing solutions were sufficiently satisfactory to discourage investigation of alternatives (e.g., ongoing use of email attachments for exchange of drawings; use of PC Anywhere for application sharing), or the demand was low (e.g., infrequent interaction with distant colleagues). There were also a number of engineers who wanted to use the collaborative tools, but couldn't due to infrastructure deficiencies (e.g., poor network connectivity between Division B sites in the US and in France) or deficiencies in the tools (e.g., no mechanism for sharing poster or wall-sized drawings via application sharing programs). Finally, it may be the case that the emphasis on synchronous collaboration (e.g., NetMeeting) was at the expense of asynchronous tools (e.g., TeamWave). Specifically, introduction of

asynchronous collaboration technology might have been a useful complement to the synchronous applications, particularly given the small number of overlapping work hours between Europe and the U.S. However, it is unknown whether adoption and use of asynchronous tools would have also been vulnerable to deficiencies in the available network infrastructure and user inertia (see earlier comments on heavy use of email attachments).

A second conclusion is that identified targets for change, such as adoption and use of collaborative tools, need adequate support to ensure success. The level of support varies with the complexity and novelty of the proposed tool. For example, a factor in the widespread adoption of shared calendar tools within CAR was certainly familiarity with calendars generally, and the seamless transference of knowledge and practices with paper calendars to online shared calendars. By contrast, for most CAR engineers, NetMeeting represented a completely new tool, with no analogs from past practice. Therefore, in adopting the tool engineers were asked to master both the tool itself (e.g., operation of the interface, how to establish a connection, how to share an application) and also the choreography of working with a distant colleague via the tool (e.g., trading off control of the mouse, negotiating shared references, resolving failures and surprises). In this project, we made a significant investment in one-to-one training surrounding the introduction of NetMeeting. We were also strategic in the selection of deployment targets, conferring with CAR team managers to select those with both the greatest need for NetMeeting and the highest likelihood of adopting and using NetMeeting. The one-to-one training was a success, but probably not conducted on a broad enough scale to create a quick critical mass of users (although at least within the German site, there was evidence of diffusion of NetMeeting use based on spontaneous training among engineers beyond the initial targeted users). Less successful was the approach of finding high visibility users to model NetMeeting

use, and by example, stimulate wider adoption of the tool. At least within the CAR team, engineers had much to do just in performing the required aspects of their jobs. It was unrealistic to expect that engineers would devote time to instruct colleagues in the use of a sophisticated and complex tool. In addition, some of the users we identified as the most influential adopters of new technology had already taken the initiative with application sharing by using an alternative tool (e.g., PC Anywhere) – which underlines the finding from the requirements analysis about the importance of application sharing – but did not help the effort to broaden the base of NetMeeting users.

A final conclusion is that successful deployment of collaborative tools requires a coordinated approach that involves the IT support organization at an early stage. In this project, we were fortunate to have obtained early endorsement from the IT managers within both divisions in the CAR team. Also, we were helped by the fact that within Auto 1, the IT managers reported to the human resources organization – and our key internal sponsorship came from a human resources vice president. The early endorsement meant that within the constraint of their limited resources, the Auto 1 IT managers were able to smooth many potential barriers to the project. For example, in the course of conducting other business at the European sites, IT personnel checked installation of NetMeeting on engineering workstations. IT personnel also installed and maintained an internal NetMeeting server.

4.3.3 Advice to researchers

The foremost practical recommendation for future research on collaborative tools in field settings would be to anticipate competing demands in this type of research. Specifically, adoption of novel tools with accompanying novel practices is not something that unfolds on a time scale consistent with most

projects. Therefore, researchers will confront the need to perform some level of “pump priming” – that is, there has to be some level of collaboration tool adoption and use to produce behavior and outcomes that can be used to evaluate the impact of collaborative tools. Realistic determination of resources required to produce use, particularly where none currently exists, is difficult. In this study, for example, we robustly documented the enthusiastic need for features contained in tools like NetMeeting – yet for various reasons, stimulating sufficient levels of use remained a great labor. This labor, in the form of one-on-one training, follow up visits, and ongoing encouragement of use (e.g., weekly hints via email) came at the expense of more detailed documentation of what was going on within the CAR team in general, and more specifically, what people were doing with collaborative tools. Our compromise solution, including the two survey administrations, was one way to balance the competing demands of tool deployment and training and data gathering. However, as noted earlier, this solution had certain liabilities – such as poor ability to tease out details of engineering practice and the failure to capture all potential respondents (e.g., lack of response from US NetMeeting users).

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APPENDIX A: RESEARCH PLAN DOCUMENT

Promoting Project Team Collaboration

"Auto1"/University of Michigan/National Institute for Standards and
Technology
October 4, 1999

Summary

- Researchers at the University of Michigan (UM) and the National Institute of Standards and Technology (NIST) propose a partnership to explore the implementation of collaboration tools with a geographically distributed engineering team at "Auto1."
- The research will focus on improved coordination and communication within the engineering team through systematic introduction and evaluations of computer-supported collaborative tools.
- UM and NIST offer expertise and experience in facilitating the introduction of computer supported collaborative tools.
- Auto1 will benefit from the UM/NIST teams' expertise and will contribute to research of national importance.

Rationale

Effective management

Despite the increasing prevalence of geographically distributed organizations, most firms do not yet effectively manage dispersed workforces. Successfully managing geographically distributed work can become a strategic advantage for multinational companies.

New methods of collaboration

The rise of the Internet, and particularly of collaboration tools that run over the Internet, suggest new ways to make distributed work more like co-located work. Examples include:

- Application sharing tools, such as Microsoft NetMeeting or Lotus SameTime, which allow remote collaborators to view and modify common documents or drawings, much as workers would do sitting side-by-side at the same computer.
- Awareness applications, such as America Online's ICQ, that allow remote workers to obtain information about what their colleagues are doing much as workers in a shared office do by walking down hallways and glancing in offices.
- Desktop videoconferencing, such as iXL's iVisit, that allow remote workers to see each other, much as co-located workers do in face to face meetings.

Effective communication and coordination

Little is known about whether and how emerging computer supported collaborative tools actually boost the effectiveness of communication and coordination among distributed workers. This study focuses on identification of

technologies and practices that will improve product development and manufacturing at AUTO1.

Auto1's Involvement

- AUTO1 will partner with the UM/NIST team in exploring collaboration tools in the context of product engineering.
- AUTO1's human resources manager and appropriate colleagues from the information technology and human resources departments will monitor and provide insight in the research process.
- The research exploration will include:
 1. Analysis of current work practices most impaired by geographic dispersion of the engineering team.
 2. Selective introduction of collaboration tools to match these practices.
 3. Assessment of the cost and effectiveness of these tools.

Benefits

The benefits to AUTO1 of participation in the project include:

- Subsidized research focused on improving AUTO1 product development through the use of computer supported collaborative tools. Choices about tool introductions will be informed by UM and NIST researchers with thorough knowledge of the capabilities of these tools, as well as knowledge of how to shape tool introductions to insure the highest possible probability of successful use. This expertise and experience will be available at no cost to AUTO1. See the attached "Research Team Qualifications" for details.
- Potential cost reductions associated with less travel and less long distance phone communication.
- Potential increased participation at meetings with associated improvement in cross-divisional input.
- Potential enhanced ability to share documents, drawings, and data among distributed engineers.
- Obtaining key benchmark data to evaluate the value of wider adoption of collaboration tools as well as a picture of longer-term improvements associated with collaboration tool use.
- Contribution to the development of science and commerce in the United States, by providing data on how engineers in actual work situations use collaboration tools.

Risks

Risk

Response

- | | |
|---|---|
| A. The research may impair the performance of AUTO1 engineers or compromise AUTO1 proprietary information. | The UM/NIST team has an extensive track record of successful research within operational units of US and foreign companies (see the attached "Research Methods" for details). |
| B. Collaboration tools may fail or be perceived as failures, and therefore jeopardize subsequent technology initiatives. | Technology failures can be minimized through tool selection that fits observed practices within the Dual Clutch Transmission (CAR) group, and through personalized coaching that introduces best techniques for tool use. |
| C. Overhead associated with technology introductions may overwhelm AUTO1 information technology and human resource personnel. | Introduction of collaboration tools with sufficient lead-time to ensure that installation of client applications occurs smoothly and demands of collaboration tools on infrastructure are well understood, with an emphasis on tools that have low installation and maintenance requirements. |

Timeline

- There are four phases to the research exploration: Planning, baseline data collection, technology interventions, and evaluation. See the attached "Research Milestones" for details.
- The end of each phase defines a reporting point to AUTO1, concluding with an overall project summary at the end of the research period.
- Initial funding from NIST to the University of Michigan to support this project has an end date of September 30, 2000.
- Specific near-term deadlines will be sensitive to AUTO1 engineering and production deadlines.

RESEARCH MILESTONES

Phase	Time	Key events
1. Planning	Months 0 - 2	<ul style="list-style-type: none"> • Face-to-face meeting among the principals (i.e., UM/NIST scientists, management of the CAR group, relevant information technology and human resource staff, AUTO1 liaison). The purpose of this meeting will be to align expectations and clarify deadlines and deliverables. • Coordination with HR personnel on training strategies, and coordination with information technology personnel on both near-term needs (e.g., installing software to do Web-based questionnaire administration) and longer-term needs (e.g., forecasting demand for support of tool installation etc.).
2. Baseline data collection	Months 2 - 4	<ul style="list-style-type: none"> • Baseline data collection (refer to “Research Methods” for further details): <ul style="list-style-type: none"> - Distribute questionnaire - Conduct interviews - Assess technology infrastructure
3. Technology intervention	Months 4 - 10	<ul style="list-style-type: none"> • Evaluate baseline data and determine what these data suggest in terms of tool introductions. • Rollout candidate technologies and complete training. • Observe the tools in use.
4. Follow-up and evaluation	Months 10 - 12	<ul style="list-style-type: none"> • Administer follow-up questionnaire. • Analyze of pre- and post-technology introduction responses to determine the impact of collaboration tools in use. • Generate summary report for AUTO1 management.

Research Methods

- We expect and plan to have minimal repercussions on AUTO1 workers as a result of this research exploration.
- Every worker in the CAR group will be asked to complete a 20-minute questionnaire to measure baseline communication and coordination activities (usually administered via the Web), and a final follow-up questionnaire.
- A representative sub-set of workers in the CAR group (e.g., sampling by organizational status and task responsibility) will be asked to participate in a 30-minute interview conducted on site.
- Training may be aimed at groups and/or individual engineers.
- AUTO1 may expect additional interaction from the UM/NIST team, such as “silent” participation at meetings, and logging of text exchanges, in order to further collect data unobtrusively.
- Across all of these data collection efforts, identities of the AUTO1 organization and specific workers will be appropriately concealed in resulting publications and all data collection will conform with standards dictated by the University of Michigan human subjects review board.

Research Team Qualifications

Expertise

- Expertise and a history of implementing collaboration tools in corporate settings, including high technology and automotive organizations. For instance, Dr. Tom Finholt from UM is the principal investigator on a recent project using collaboration tools in a multi-national organization, to improve communication and coordination of team members located in Germany, England, India and the United States.
- Expertise in selecting and evaluating collaborative technology. The UM group includes researchers and scientists who specialize in human-computer interaction, who investigate the use of collaborative technology in laboratory and field settings.
- Expertise with product development teams and related research. For instance, Dr. Bob Allen from NIST will be joining the team. His research includes recent deployment and assessment of an engineering notebook integrated with other collaborative tools for a geographically dispersed product design team.
- Expertise with general manufacturing collaboration requirements and capabilities. The NIST Manufacturing Collaboratory research project is implementing and assessing collaboration tools in one other scenario (for manufacturing research). Lessons learned from this deployment can be applied to the AUTO1 effort.
- Access to related research expertise through association with the NIST Manufacturing Collaboratory, including research at the University of Saskatchewan in evaluating groupware and the University of Maryland in Internet-based knowledge management.
- Access to NIST research engineers and scientists with broad experience in manufacturing systems integration.

A solid foundation of experience in research

Our expertise and experience allows us to offer superior recommendations and support through the implementation of collaboration tools. For instance, our training on collaboration tools includes not only features of the tools, but also effective use of the features to avoid known limitations and to best exploit benefits of the technology

We will build on this foundation to avoid past failures and to exploit successes in collaboration tool implementation.

Biographical Material

University of Michigan (UM)

Thomas A. Finholt, Ph.D. (Carnegie Mellon University), **Project Manager.**

Director of the Collaboratory for Research on Electronic Work (CREW),
Principal Investigator on NIH, NSF and industry funded collaboration
technology research,

Research Scientist at The University of Michigan's School of Information
and

Assistant Professor in the Department of Psychology

Elizabeth E. Wierba, Ph.D. (University of Michigan)

Research Fellow at CREW, Faculty member of The University of
Michigan's School of Information, Adjunct Lecturer in the Department of
Psychology and the School of Business Administration.

Kristen Truong, B.A. (University of Michigan)

Research Assistant at CREW, Masters Candidate at The University of
Michigan's School of Information.

National Institute of Standards and Technology (NIST)

Amy Knutilla, P.E.

Industrial Engineer in the Manufacturing Systems Integration Division of
NIST's Manufacturing Engineering Laboratory, and co-project leader for
the NIST Manufacturing Collaboratory Project.

Michelle Steves

Computer Scientist in the Manufacturing Systems Integration Division of
NIST's Manufacturing Engineering Laboratory, and co-project leader for
the NIST Manufacturing Collaboratory project.

Robert Allen, P.E., Ph.D. (University of Maryland)

Mechanical Engineer in the Engineering Design Technologies group of
NIST's Manufacturing Engineering Laboratory.

APPENDIX B: SURVEY INSTRUMENT, TIME 1

Note: All corporate, team, and individual identifying information has been deliberately obscured.

survey1 - Netscape
File Edit View Go Communicator Help

Survey on geographically distributed work at [redacted]

1. Please enter your full name (e.g. John K. Smith):

2. Where is your primary office located?

<input type="radio"/> [redacted], DE	<input type="radio"/> [redacted], MI
<input type="radio"/> [redacted], IL	<input type="radio"/> [redacted], MI
<input type="radio"/> [redacted], FR	<input type="radio"/> [redacted], DE
<input type="radio"/> Other	

List other here:

3. Please select the description that best describes your primary office (the office you selected in Question 2).

<input type="radio"/> Solo Office
<input type="radio"/> Shared Office
<input type="radio"/> Open Plan
<input type="radio"/> Other

List other here:

4. Please indicate the type of workstation you use most of the time.

<input type="radio"/> Windows95/98	<input type="radio"/> Windows NT
<input type="radio"/> HP Unix	<input type="radio"/> Sun Unix
<input type="radio"/> IBM Unix	<input type="radio"/> SGI Unix
<input type="radio"/> X Terminal	<input type="radio"/> Macintosh
<input type="radio"/> Other	

List other here :

Document: Done

survey1 - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Please answer the following questions to the best of your ability using a 1 to 10 scale, with 10 being most likely and 1 being least likely.

How likely would you be to adopt for regular use software that... **Scale from 1 to 10**

5. ...lets you and your co-workers share information about your schedules on a common calendar?

6. ...lets you integrate caller ID, click to dial, and conference calling from your workstation?

7. ...lets you and your co-workers share information about availability and presence?

8. ...lets you and your co-workers simultaneously mark up a drawing when you are at your desks?

9. What is your job title?

10. How much do you like your job?

11. On which project are you currently working (check all that apply)?

☐ ☐

12. For your work on the project, please indicate the percentage of your work that fits each of the following descriptions.

Type of Work Flow	Percentage of Work
a. INDEPENDENT work flow, where work and activities are performed by you and your co-workers independently and do not flow between you.	<input type="text"/>
b. SEQUENTIAL work flow, where work and activities flow between you and your co-workers in one direction.	<input type="text"/>
c. RECIPROCAL work flow, where work and activities flow between you and your co-workers in a reciprocal "back and forth" manner over a period of time.	<input type="text"/>
d. TEAM work flow, where you and your co-workers diagnose, problem-solve and collaborate as a group at the SAME TIME to deal with the work.	<input type="text"/>

Total = 100%

13. Please indicate your age:

14. Please indicate your gender: ☐ male ☐ female

15. Please indicate your nationality:

File Edit View Favorites Tools Help

16. How long have you been employed at _____ years and _____ months.
Please answer in years and months.

17. Are you a native English speaker?
☐ Yes (continue to **Question 22**)
☐ No (continue to **Question 18**)

Please indicate your level of agreement with the following statements:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
18. I speak English well.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
19. I understand spoken English well.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
20. I write English well.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21. I read English well.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

22. Consider your work on the _____ team. Please choose those people you most often communicate with for work-related reasons. Selected names on the list will appear automatically in following questions. If the name of a co-worker is not listed, please type in his/her name.

Co-workers: _____ **Co-workers you communicate with frequently for work-related purposes:**

—Select from Here—

Germany—

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

k. _____

l. _____

m. _____

n. _____

File Edit View Favorites Tools Help

23. For each co-worker you selected, please provide the number of times in a typical week that you communicate for work-related purposes face to face, by phone and by email.

Co-workers you communicate with frequently:	How many times per week do you communicate for work-related purposes...		
	face to face?	by phone?	by email?
a.			
b.			
c.			
d.			
e.			
f.			
g.			
h.			
i.			
j.			
k.			
l.			
m.			
n.			
o.			

File Edit View Favorites Tools Help

24. For each co-worker you selected, please provide the number of times in a typical week you communicate for work-related purposes by conference calls, by video conference, or by collaborative tools (e.g., application sharing tools like PC Anywhere or NetMeeting, which allow two team members to simultaneously view and modify common documents or drawings).

Co-workers you communicate with frequently:	How many times per week do you communicate for work-related purposes...		
	by conference calls?	by video conference?	by collaborative tools?
a.			
b.			
c.			
d.			
e.			
f.			
g.			
h.			
i.			
j.			
k.			
l.			
m.			
n.			
o.			

File Edit View Favorites Tools Help

25. Consider your social communication with co-workers on the _____ team. Please choose those people you most often communicate with socially. This list can overlap with the previous list for work-related communication. Selected names will appear automatically in following questions. If the name of a co-worker is not listed, please type in his/her name.

Co-workers:	Co-workers you communicate with socially:
-Select from Here-	a. <input type="text"/>
Germany-	b. <input type="text"/>
	c. <input type="text"/>
	d. <input type="text"/>
	e. <input type="text"/>
	f. <input type="text"/>
	g. <input type="text"/>
	h. <input type="text"/>
	i. <input type="text"/>
	j. <input type="text"/>
	k. <input type="text"/>
	l. <input type="text"/>
	m. <input type="text"/>
	n. <input type="text"/>
	o. <input type="text"/>

26. For each co-worker you selected, please provide the number of times per week you communicate with this person for non-work related purposes for each medium.

Co-workers you communication with frequently:	How many times per week do you communicate socially....		
	face to face?	by phone?	by email?
a. <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
b. <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
c. <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
d. <input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Co-workers you communicate with frequently:			I consider this person to be a ...	
			Friend	Aquaintance
a.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
b.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
c.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
d.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
e.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
f.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
g.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
h.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
i.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
j.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
k.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
l.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
m.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
n.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>
o.	<input type="text"/>		<input type="radio"/>	<input type="radio"/>

28. Estimate the number of days you spent at each of the following sites **during the previous six months (June 1, 1999 - November 30, 1999)**. Please enter the number of days by each site. **Leave the site of your primary office blank.** Enter zero for sites you did not visit.

a. <input type="text"/> Germany	<input type="text"/>
b. <input type="text"/> Michigan	<input type="text"/>
c. <input type="text"/> Michigan	<input type="text"/>
d. <input type="text"/> Illinois	<input type="text"/>
e. <input type="text"/> France	<input type="text"/>
f. <input type="text"/> Germany	<input type="text"/>
g. Any other place not listed :	<input type="text"/>
h. Any other place not listed :	<input type="text"/>

	Never	A few times a year	Once a month	Once a week	Once a day	More than once a day
a. [redacted] Germany	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b. [redacted] Michigan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c. [redacted], MI	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
d. [redacted] Illinois	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
e. [redacted] France	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
f. [redacted] Germany	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
g. [redacted] [redacted]	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
h. [redacted] [redacted]	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please think about the [redacted] project with which you are most involved. In this section, we are interested in your perceptions of how your co-workers feel about being on the [redacted] project team. For each statement please indicate your level of agreement.

	Local Co-workers	Distant Co-workers
30. Team members consider the success of the [redacted] project team as their success.	<input type="radio"/>	<input type="radio"/>
31. Team members view criticism of the [redacted] project team as a personal insult.	<input type="radio"/>	<input type="radio"/>

Please continue to think about the [redacted] project and the people involved. In this section, we are interested in feelings about [redacted] co-workers. For each statement please indicate your level of agreement.

I trust that my fellow [redacted] team members ...	Local Co-workers	Distant Co-workers
32. will keep the promises they make	<input type="radio"/>	<input type="radio"/>
33. are competent in performing their jobs	<input type="radio"/>	<input type="radio"/>

File Edit View Favorites Tools Help														
34. express their true feelings about important issues	<input type="button" value="v"/>	<input type="button" value="v"/>												
35. care about my well-being	<input type="button" value="v"/>	<input type="button" value="v"/>												
36. can contribute to the success of our organization	<input type="button" value="v"/>	<input type="button" value="v"/>												
37. care about the future of our organization	<input type="button" value="v"/>	<input type="button" value="v"/>												
38. have consistent expectations of me	<input type="button" value="v"/>	<input type="button" value="v"/>												
39. would acknowledge their own mistakes	<input type="button" value="v"/>	<input type="button" value="v"/>												
<p>Please continue to think about the [redacted] project and the people involved. In this section, we are interested in the quality of information exchange with [redacted] co-workers. For each statement please indicate your level of agreement.</p>														
<table border="1"> <thead> <tr> <th>Local co-workers</th> <th>Distant co-workers</th> </tr> </thead> <tbody> <tr> <td>40. It is difficult to schedule common meeting times with my co-workers.</td> <td><input type="button" value="v"/></td> </tr> <tr> <td>41. My co-workers provide timely information about changes in current plans.</td> <td><input type="button" value="v"/></td> </tr> <tr> <td>42. People I need to communicate with are difficult to find.</td> <td><input type="button" value="v"/></td> </tr> <tr> <td>43. I pass on new information to my co-workers that I think will be useful to them.</td> <td><input type="button" value="v"/></td> </tr> <tr> <td>44. My co-workers pass on information that they think might be useful to me.</td> <td><input type="button" value="v"/></td> </tr> </tbody> </table>			Local co-workers	Distant co-workers	40. It is difficult to schedule common meeting times with my co-workers.	<input type="button" value="v"/>	41. My co-workers provide timely information about changes in current plans.	<input type="button" value="v"/>	42. People I need to communicate with are difficult to find.	<input type="button" value="v"/>	43. I pass on new information to my co-workers that I think will be useful to them.	<input type="button" value="v"/>	44. My co-workers pass on information that they think might be useful to me.	<input type="button" value="v"/>
Local co-workers	Distant co-workers													
40. It is difficult to schedule common meeting times with my co-workers.	<input type="button" value="v"/>													
41. My co-workers provide timely information about changes in current plans.	<input type="button" value="v"/>													
42. People I need to communicate with are difficult to find.	<input type="button" value="v"/>													
43. I pass on new information to my co-workers that I think will be useful to them.	<input type="button" value="v"/>													
44. My co-workers pass on information that they think might be useful to me.	<input type="button" value="v"/>													
<p>Please continue to think about the [redacted] project and the people involved. In this section, we are interested in delays you have experienced involving your [redacted] co-workers.</p>														
<table border="1"> <thead> <tr> <th>Involving local co-workers</th> <th>Involving distant co-workers</th> </tr> </thead> <tbody> <tr> <td>45. How many times in the past month was your own work delayed because you needed information, further discussion, or a decision?</td> <td><input type="text"/></td> </tr> <tr> <td>46. What was the average length of the delays you experienced before acquiring the needed information, having the discussion, or being informed of the decision?</td> <td> <input type="button" value="-Select from here-"/> <input type="button" value="-Select from here-"/> </td> </tr> </tbody> </table>			Involving local co-workers	Involving distant co-workers	45. How many times in the past month was your own work delayed because you needed information, further discussion, or a decision?	<input type="text"/>	46. What was the average length of the delays you experienced before acquiring the needed information, having the discussion, or being informed of the decision?	<input type="button" value="-Select from here-"/> <input type="button" value="-Select from here-"/>						
Involving local co-workers	Involving distant co-workers													
45. How many times in the past month was your own work delayed because you needed information, further discussion, or a decision?	<input type="text"/>													
46. What was the average length of the delays you experienced before acquiring the needed information, having the discussion, or being informed of the decision?	<input type="button" value="-Select from here-"/> <input type="button" value="-Select from here-"/>													

APPENDIX C: NETMEETING TRAINING GUIDE

NetMeeting 3.01

Installation, Troubleshooting and User Guide

Microsoft NetMeeting is a set of application and network components that enables real-time audio, video, and data communication over the Internet or Intranet.

You can work easily with other meeting participants by sharing programs. Only one computer needs to have the program, and all participants can work on the document simultaneously. In addition, people can send and receive files to work on. NetMeeting's audio and video let you see and hear other people. Even if you are unable to transmit video, you can still receive video calls in the NetMeeting video window. With the Chat feature, you can talk with multiple people. In addition, Chat calls can be encrypted, ensuring that your meetings are private. Using the Whiteboard, you can explain concepts by diagramming information, using a sketch, or displaying graphics. You can also copy areas of your desktop or windows and paste them to the Whiteboard.

NetMeeting Resources

- For complete information on NetMeeting and other sources, refer to the official Microsoft site of NetMeeting: <http://www.microsoft.com/netmeeting>
The site also has latest software downloads and information for developers and system administrators.
- For optimal performance, it is recommended that all potential participants in a meeting run the same version of NetMeeting.
- For latest NetMeeting news and discussions on common problems:
<http://www.netmeet.net>
- Please contact the following for further assistance:
Pepper Dixon (pdixon@umich.edu)

System Requirements

Operating system

- Windows 95, Windows 98, Windows NT 4.0 (with service pack 3 or later)
- NetMeeting does not run on Windows version 3.1 or beta versions of Windows 98 older than Beta 3.

Hardware (recommended)


- Pentium 200 Mhz
- 32 MB RAM
- 10 MB free hard disk space
- Sound card with microphone and headphone (for audio).
- Video capture card or a camera that provides a Video for Windows capture driver (required for video support).

Installation Instructions

Before you start:

1. It is strongly recommended that you uninstall any earlier versions of Microsoft NetMeeting before installing NetMeeting 3.01.
 - To uninstall - go to <Control Panel> and click on <Add/Remove programs>.
 - Select NetMeeting from the list and click remove.
2. Make sure that all computers run the same version of NetMeeting, preferably 3.01.
3. Download the executable file from <http://www.microsoft.com/netmeeting> and store it on a central server for easy accessibility. Make sure it is NetMeeting 3.01. You can also use the customized installation file, which has standard options already hardwired.

Installing NetMeeting 3.01:

1. **Install program.** Double click on the installation file to install the program.
2. **Launch NetMeeting.** Double click on the shortcut icon on the desktop, or choose from the <Start> menu to launch NetMeeting.
3. **Enter user information.** It will ask for various details about the user that can be changed later. Make sure to enter at least the name and the e-mail address of the user.
4. **Set up server.** Make sure you enter the default server directory address as **ils.intranet.auto1.com**. This is Auto 1's intranet NetMeeting server. This option will be grayed out if you are using customized installation file.
5. **Check audio.** It will then check for the sound card and adjust for the optimum performance. You can skip this if voice is not needed.
6. **Activate application sharing.** If you are using NT, application sharing will not be active until you explicitly activate it.
 - Go to <Tools> and then select enable sharing.
 - It will install a small patch then ask you to restart.
 - Once you restart the computer, application sharing should work.**Note** – You may have to be logged in as Administrator to perform this.
7. **Check directory.** Make sure you are logged on the pre-determined directory server.
 - Click on **Find someone in a directory**  to bring up the directory list.
 - Check whether you are logged on the server.
 - If not click on **Call** and select log on the server.
 - To change the server, type in the server address in the **Select a directory** box.

Note -- by changing the server you do not change the server you were logged on. You will have to explicitly change the default directory server by:

- On the **Tools** menu, click **Options**.
- On the **General** tab, under **Directory Settings**, in **Directory**, type or click the new directory server name.

NetMeeting Interface






















Main Buttons		
 Place a Call	 End Call	 Find someone in a directory
 Start Video/Stop Video	 Picture-in-Picture	 Adjust Audio Volume/ View Participant List
 Share Program	 Chat	 Whiteboard
 Transfer Files		
Transfer File Buttons		
 Add Files	 Remove Files	 Send All
 Stop Sending	 View Received Files	
Call Status Buttons		
 In a Call	 No Connections	 Do Not Disturb
 In a Secure Call	 Logged On	 Not Logged On




Figure A

To Place/Accept a Call

Direct calling:

- In the Address bar ('1' in the above figure A), type **one** of the following:
 - computer name
 - IP address
 - Email address (The person has to be logged on the ILS server)
- Click the **Place Call** button.

Calling through the directory:

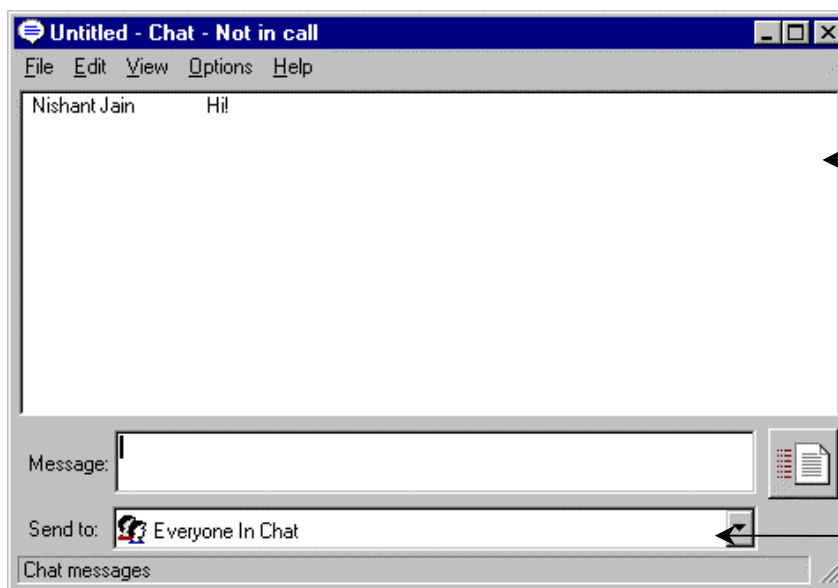
- Click the Find Someone in a Directory () button.
- In **Select a directory**, click an address book or directory.
- Type the name of the person you want to call, or select it from the list.
- Click **Call**.

Accepting a call:

1. A message box about incoming calling appears.
2. Click **Accept** to enable the caller to joint the meeting.

How to Use Text Based Chat

1. Click on the 'Chat' icon below the menu bar. It will bring up the chat box as shown.
2. To send a message, type the text in the 'Message' field, and hit enter.
3. If you want to send the message only to a particular participant in the conference then pull down 'Send to' menu and click on the participant you wish to send the message.

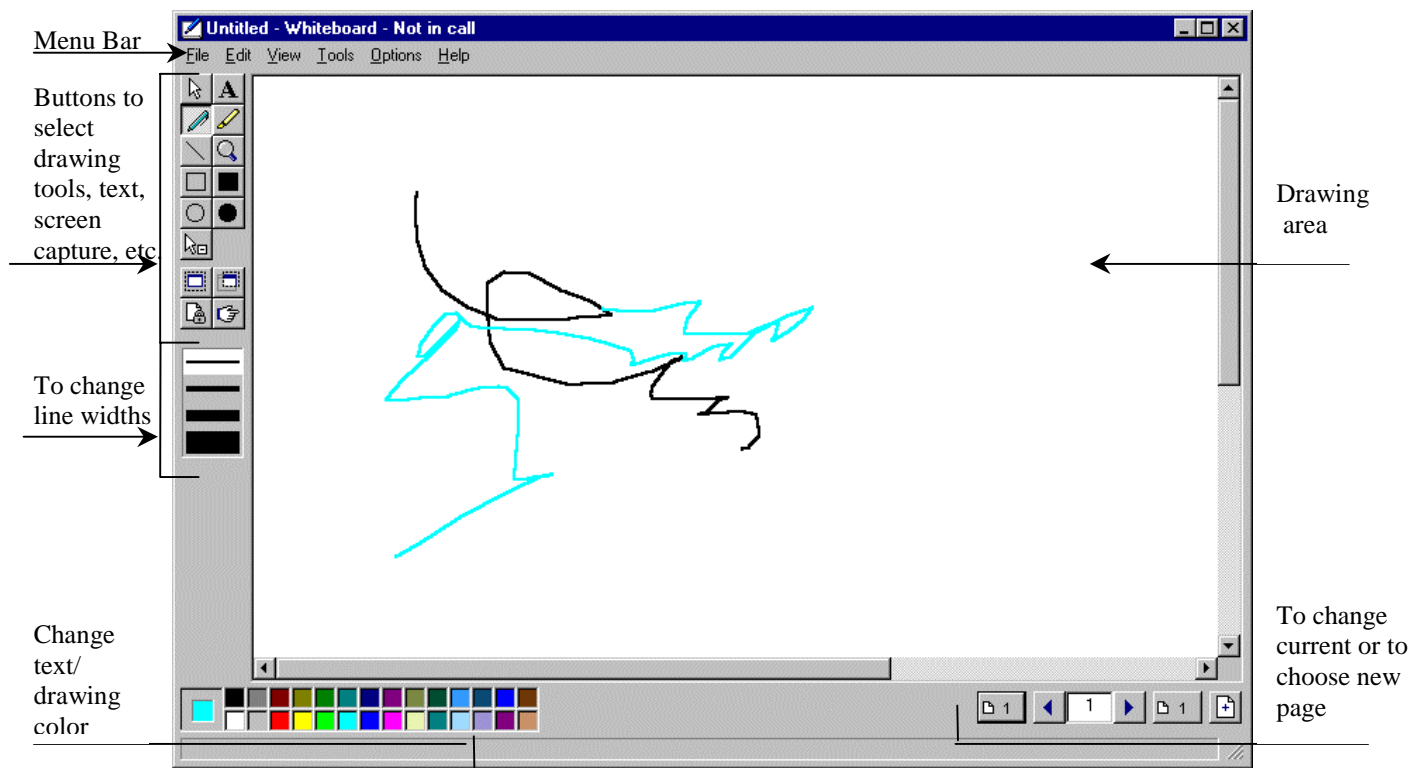


The name of the sender and his/her message would be displayed here.

Type your message here

How to Use the Whiteboard

- The whiteboard is a simple drawing environment which enables you to draw simultaneously with other users. One can also import images, graphics, graphs or text.



1. Click on the 'Whiteboard' icon below the menu bar. This will bring up the board as shown above.
2. Draw, type or import files using the provided features.

Sharing Programs

- Sharing programs allows meeting participants to view and work on files simultaneously. For example, you may have a Microsoft Word document that several people need to work on. You can open the document on your computer, share it, and then everyone can provide his or her comments directly in the document.
- All meeting participants can share programs during a meeting. The shared programs of each participant appear in separate shared program windows on the other participants' desktops.
- Only the person who has opened the file is required to have the program on their computer. Other participants can work on the document without having the program.
- Only one person can be in control of a shared program at a time.
- If **Controllable** appears in the title bar of the shared program window, the person who shared the program has control and is allowing others to work in the program.
- If the mouse pointer has a box with initials, then another meeting participant has control of the program.

TO SHARE A PROGRAM:

1. Open the program you want to share.
2. Click the **Share Program** button.
3. In the **Sharing** dialog box, click the name of the program you want to share. Click **Share**.
4. Be sure not to cover up the program you are sharing with other windows. This blocks the view of the program to others.

Caution

- If you share a Windows Explorer window, such as My Computer, Control Panel, or a folder on your computer, you will be sharing all Explorer windows you have open. Also, once you have shared such a window, every program you start while you are still in the meeting is shared with the other participants automatically.

Notes

- Make sure everyone in the meeting has the same screen resolution, or else people with lower resolution will have to scroll excessively to view the shared application.
- You can also click the NetMeeting icon in the status area of your taskbar, and then click the **Share Program** button on the quick-access toolbar.
- You can share more than one program at a time and several people can share programs simultaneously.
- If you open a program after the **Sharing** dialog box opens, click the **Share Program** button again to add the new program to the list.
- It is recommended that you do not select the **Share in true color** check box. True color causes program sharing, particularly over dial-up connections, to be very slow.

To allow control of a shared program:

1. In the **Sharing** dialog box, click **Allow Control**.
2. In the main NetMeeting window, right-click the name of a person you want to work in the program, and then click **Grant Control**.

Notes

- If **Allow Control** appears dimmed, you have not shared a program. You must share a program or your desktop before you can allow control.
- You can click **Allow Control** at any time during the meeting. When you click it, the button name changes to **Prevent Control**. If you click **Prevent Control**, other participants cannot work in the shared program until you click **Allow Control** again.
- When a participant requests control, NetMeeting displays a message asking your permission. If you want to grant permission automatically, in the **Sharing** dialog box, select the **Automatically accept requests for control** check box.
- If you do not want anyone other than the person who has control currently to take control, select the **Do not disturb with requests for control right now** check box.
- To take back control of the program once you have shared it, click anywhere on your desktop. Only one person can control a program at a time.

TO STOP SHARING A PROGRAM:

1. Click the **Share Program** button.
2. In the **Sharing** dialog box, click **Unshare** to stop sharing one program or **Unshare All** to stop sharing all programs.

Notes

- If you do not have control of the mouse pointer, click or press any key to take back control.
- To quickly stop sharing program – click **Prevent Control** or hit <Esc>.
- Only the person who originally shared a program can stop sharing it.

Saving and transferring files:

1. Once the shared file has been altered, you may want to save these changes. The file can only be saved by the user who opened the program for this file.
2. From the **Tools** menu, click **File Transfer**.
3. In the File Transfer dialog box, click **Add File** if file does not appear in window.
4. From the File Transfer dialog box, click **Send a File** to transfer file.

General Issues and Troubleshooting Tips

- Quitting and restarting NetMeeting can solve most of the problems.
- There is a limit of eight participants who can call a single computer. To go around this limitation one can call other participants in the same meeting.
- Make sure everyone in the meeting has the same screen resolution, or else people with lower resolution will have to scroll excessively to view the shared application.
- You can also **Host a Meeting**, which can be password protected to prohibit outsiders to join the meeting.
- Select **Do not Disturb** from **Call** to automatically reject unwanted callers.
- Certain NetMeeting features might not work as desired when there is a firewall in place.
To enable NetMeeting 3 multipoint data conferencing—program sharing, Whiteboard, Chat, file transfer, and directory access—your firewall only needs to pass through primary TCP connections on assigned ports. NetMeeting audio and video features require secondary TCP and UDP connections on dynamically assigned ports. Therefore, if you establish connections through firewalls that accept only primary TCP connections, you will not be able to use the audio or video features of NetMeeting. Please download the resource kit for complete instructions - <http://www.microsoft.com/windows/NetMeeting/Corp/ResKit/default.ASP>
- If you are sharing graphically intensive applications, stopping the video might improve the performance.
- NetMeeting does not work with Windows 2000.
- If application sharing does not work on an NT, make sure it has service pack 3.0 and its 'application sharing' has been enabled.
- Application sharing does not work well between versions 2.1 and 3.0.
- If you are unable to connect with someone on LAN using TCP/IP -
Your environment may not be configured for TCP/IP networking, or TCP/IP may not be installed and configured correctly. On a Windows 95 computer, TCP/IP is not installed as a default network protocol when you set up a network configuration. Additionally, on a Windows 95-only LAN, TCP/IP must be configured manually to specify IP addresses, configure LMHOSTS files for computer name resolution, and configure HOSTS files for domain name resolution. Please check the resource kit for details - <http://www.microsoft.com/windows/NetMeeting/Corp/ResKit/default.ASP>
- If the shared application slows down considerably, it might be helpful to close some of the other running applications.
- To promote ad-hoc meetings, it is recommended to put NetMeeting in the start up folder, so that NetMeeting starts up by default and the user logs on a directory server for easy accessibility.

Protocols to be Observed While in Collaboration Mode

While in the collaboration mode, the mouse control for different participants becomes quite irritating and unmanageable. The control becomes more cumbersome as the number of participants increases. As there is no selective collaboration mode therefore if you choose to collaborate, all the participants can join in.

While collaborating among more than three participants observing the following social protocols will help in better coordination -

- If there is one person who is presenting or showing documents then it is recommended that it be done in a sharing mode rather than in collaborating mode.
- While working on the same document or any other presentation together, it is important to rotate the control. It can be done in -
 - Go sequentially and if pointer does not move for 3-4 seconds then the next person takes control. This sequence can be decided using chat or audio.
 - One person controls the meeting and the person who wants to take control indicates by typing in the chat window.
 - If you have a good audio connection (or have a telephone conference set up) the turn taking could be decided by announcing. Make sure you say your name too, to establish your identity.

Social Protocols to Increase the Productivity of the Conference

- As much as possible make sure you have met the person face to face before trying to collaborate via NetMeeting.
- Use a phone conference to handle audio. Internet audio is still miles behind the quality of the plain old telephone system.
- A NetMeeting session works best when you have a specific meeting already set up and are using the same server to locate all the members.
- Make sure you dial into one computer and not each other in ad-hoc manner. This will ensure the meeting to be better moderated and the network traffic will be at its minimum.
- Do not try to be too ambitious with NetMeeting. It works best when you have a specific goal and 1-2 documents/images/sheet to share. Start with simple goals and as you gain familiarity increase the complexity of conferences.
- Have a specific time limit and agenda, just as you would have for any face to face meeting.
- Make sure the agenda has been pre-distributed via e-mail.
- To make sure that you are always visible to your NetMeeting collaborators, put the program in your start up. This way NetMeeting will launch as soon as you switch on your machine.

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APPENDIX D: COMPARISON OF PRESENCE AWARENESS TOOLS

COMPARATIVE ANALYSIS OF ICQ AND MSN MESSENGER

"Auto1"/University of Michigan

November 1, 2000

Elizabeth Wierba, Pepper Dixon, Thomas Finholt, Sameer Patil

INTRODUCTION TO INSTANT MESSAGING

Home users have used instant messaging (IM) for quite some time. IM is used for presence awareness and instantaneous communication. This analysis focuses on determining its usability and effectiveness in a corporate setting. Collaborative work tools that enable virtual meetings, collaborative sharing, and chat rooms are important for a company with employees who cannot meet face to face (Godefroid, Herbsleb, Jagadeesan and Li, 2000). IM allows easy communication between work teams and departments spread over various geographic locations (Herbsleb and Grinter, 1999). In the end of 2000, AOL Instant Messenger claimed 80 million users who sent 750 million messages a day (Godefroid, Herbsleb, Jagadeesan and Li, 2000; Zaret, 1999). IM may be an effective collaborative tool for large organizations (Godefroid, Herbsleb, Jagadeesan and Li, 2000). Advantages of IM as a collaborative work tool include:

- Cost savings: IM saves costs of making long distance telephone calls and sending faxes.
- Time savings: Instantaneous nature of IM saves time by avoiding the delays associated with asynchronous forms of communication such as email, voice mail or postal mail.
- Efficiency: IM may increase employee efficiency by making co-workers instantly available. For example, problems can be solved more efficiently when an internal expert is online and available to chat.
- Customer service: IM may be used to create and maintain bonds between an organization and its customers.

There are several possible ways of implementing IM within an organization. Developing a proprietary IM application allows the organization to design the IM software to work only with others using the same software. Organizations can thus ensure that employees are communicating with other co-workers, or clients and focusing on the task instead of using IM for non-work purposes.

Comparing IM Clients

Two popular IM clients are MSN Messenger and ICQ. At the time that these clients were selected for comparison, these were the only options available for corporate use. When describing the features of each IM client, the term *user* refers to the individual actively using the software and *associate* refers to any third party user. A comparative section follows a description of MSN Messenger and ICQ. Lastly a recommendation for specific IM client is identified.

MSN Messenger (MM)

Key Features:

- Reports the status of a user's associates. The status can be offline, out to lunch, on the phone, away, be right back, busy and online and allows the user to indicate his/her availability by setting his/her status.

- Alerts the user when any of a his/her associates come online.
- Provides the capability to hold instant text conversations with one or more online associates.
- Stores the associate list on the server side (as opposed to the local computer), which allows for use of MM from any computer installed with MM.

Additional Features:

- Provides a typing indicator which informs users when their associate is typing while engaged in a conversation.
- Provides the capability to block particular associates from receiving the user's status information.
- Provides the capability to transfer files to/from associates.
- Provides the capability to make free telephone calls to any telephone in the US/Canada using an IP-to-Phone gateway.
- Provides the capability to initiate a NetMeeting call.
- Allows a user to change the way their name is viewed by others.
- Provides continuous flashing links to news and information linked with MSN.com, if desired.

ICQ 2000a Beta (ICQ)

ICQ is a popular IM application with over 50 million registered users in October 2000. It can function in two different modes - simple and advanced. The advanced mode is designed for expert power users and is rich with features such as To Do lists, Reminders, Pagers etc.

Since our focus is mainly on the instant messaging features, we explored the Simple Mode of the 2000 Beta version. This mode provides the basic features of ICQ without overwhelming the user with supplementary functionality.

Key Features:

- Reports the status of a user's associates. The status can be available, free for chat, away, not available, occupied, do not disturb, privacy and offline.
- Alerts the user when any of a his/her associates come online.
- Provides the capability to send instant text messages to associates.
- Provides the capability to hold instant text chats with one or more online associates.
- Allows the user to indicate his/her availability by setting how his/her status will appear either to all associates or selectively to particular associates.

Additional Features:

- Provides the capability to transfer files and URLs to/from associates.
- Stores the associate list on the local computer.
- Stores a history of all instant messages.
- Provides the capability to organize the contact list into various categories.

Evaluation

We conducted a test to evaluate these two IM clients.

- Eight users
- Each used both clients for one week
- They offered feedback regarding their functionality and usability.¹

The main advantages of MM were simplicity and ease of use from multiple computers while the main advantages of ICQ were the variety of features and high degree of customizability. The main disadvantages of MM were blinking advertisements and lack of customization capabilities while those of ICQ were the difficulties involved in using from multiple computers and spam. Both MM and ICQ (customer-oriented IM clients) pass through a central server located on the public Internet and are not encrypted leading to security concerns especially for discussion of sensitive work information.

Comparative Summary

Feature	MSN Messenger	ICQ
Free	Yes	Yes
Simple to install and use	Yes	No
Lightweight	Yes	No
Allows free phone calls	Yes	No
Tightly linked with NetMeeting	Yes	No
Easy to use from multiple computers	Yes	No
Rich in features	No	Yes
Highly customizable	No	Yes
Logs history	No	Yes
Secure	No	No
Required to register for unwanted email account	Yes	No
Advertisements	Yes	No
Spam	No	Yes

¹ Users were completed surveys via email asking about their experience with the IM clients. Two sample surveys follow at the conclusion of this paper.

ICQ Groupware

Based on the above analysis, we see that neither MSN Messenger nor ICQ are suitable for corporate use as is. This is primarily due to the lack of security mentioned above. These security concerns are especially salient to automobile companies who develop innovative designs. Such security and privacy issues are acknowledged problems in the development of presence and availability services (Godefroid, Herbsleb, Jagadeesan and Li, 2000).

In order to provide a more secure service, ICQ provides an application called ICQ Groupware. ICQ Groupware is very similar to the general-purpose version and was developed for use within organizations. The system includes an ICQ Server Component, a database component, and a client component. It can be set up over any TCP/IP network including LAN, Internet, and dial-up networks.

Key Features:

- ICQ client features are the same as those of the general-purpose version discussed earlier (Group chat, online/offline messaging, file transfer, and collaborative browsing).
- Features of the server and database component include a flexible server user-interface, system directory and database functions, offline messaging store and forward, and broadcasting.
- The ICQ Groupware system can work from behind firewalls. There are no necessary changes to the system when both the client and server components are behind the same firewall and no users are separated by firewalls. Messages are encrypted whenever the recipient is beyond the company's firewalls.

Disadvantages:

- Steep learning curve.
- Cumbersome to use from multiple computers.

Installation:

There is no cost associated with the ICQ Groupware Beta system. The downloaded version is preconfigured for a maximum of 200 users. Organizations with more than 200 users will be charged for the total number of users.

System requirements for the server operating system are Window NT 4.0 service pack 3 or higher on a server or a workstation. The client operating system will run on Windows 95, Windows NT 4.0 or higher.

Despite its disadvantages, its other features and advantages discussed earlier make ICQ Groupware an effective instant messaging solution for an organization.

Sample Email Interviews

The following transcript reflects survey data collected by University of Michigan research assistant Pepper Dixon. Interviewee response is in italics.

MSN Messenger Survey

Pepper Dixon wrote:

Hi,

We have been using Messenger for two days and I'm anxious to hear about your experience so far. Please answer the following questions.

1) Did you find the installation easy or difficult?

Very easy -- although the Passport business was potentially confusing.

2) What is the most beneficial aspect of Messenger?

The fact that updates to the contact list are current no matter where you initiate Messenger (i.e., I updated on my laptop -- then used Messenger on my desktop - the desktop reflected the laptop updates; contrast this with the apparent awkwardness of ICQ and moving the contact list from machine to machine...)

3) What is the least helpful aspect of Messenger?

I don't like the ads. I haven't figured out a way to pre-load a contact list (like the way one makes a mailing list and etc.)

4) While working, do you have Messenger minimized or maximized? Why?

I typically have it minimized and then occasionally maximize to see what's happening respond when it starts blinking. I have the sounds turned off.

5) Overall, is Messenger a helpful program in determining individuals' availability?

Very easy to use. It is helpful to know when people are online, although I don't get any feedback about where they are (at home, on the road, in their office and so forth).

6) Have you used the NetMeeting invitation function?

Not yet...

If you have not used the NetMeeting invitation function I recommend you explore this feature in the next day or so.

One way to initiate a NetMeeting is to:

1) Click Tools button

2) Scroll down to Send an Invitation

3) Scroll over to NetMeeting 3.01

4) Click the name of the person you wish to contact

Thank you,

-Pepper

ICQ Survey

Pepper Dixon wrote:

Hi,

Today marks the completion of the second testing phase. We have used and explored ICQ for a week and again, I am excited to hear from each of you. Please answer the following questions:

1) What are the advantages of ICQ?

One advantage is that ICQ is widely used; I've been able to add other ICQ users easily -- while convincing people to use Messenger is much harder (even though I think Messenger is more elegant in many ways) -- also, I did some work-related chatting via ICQ and this was quite useful (a conversation interspersed with other work over the space of an hour or two).

2) What are the disadvantages of ICQ?

The multiple identity issue and contact list management remain the biggest headaches.

3) Did you find NetMeeting difficult to initiate with other users?

Never tried NetMeeting

4) Please rate the overall usefulness of ICQ (higher is more useful).

1 2 3 4 5 6 7

6

5) Please rate the ease of usability of ICQ (higher indicates greater ease of use).

1 2 3 4 5 6 7

4 (mostly because of the contact list management issues)

Thank you for all your feedback, time and help.

-Pepper

APPENDIX E: FIGURES

Figure 1.1: Total frequency of communication with co-workers

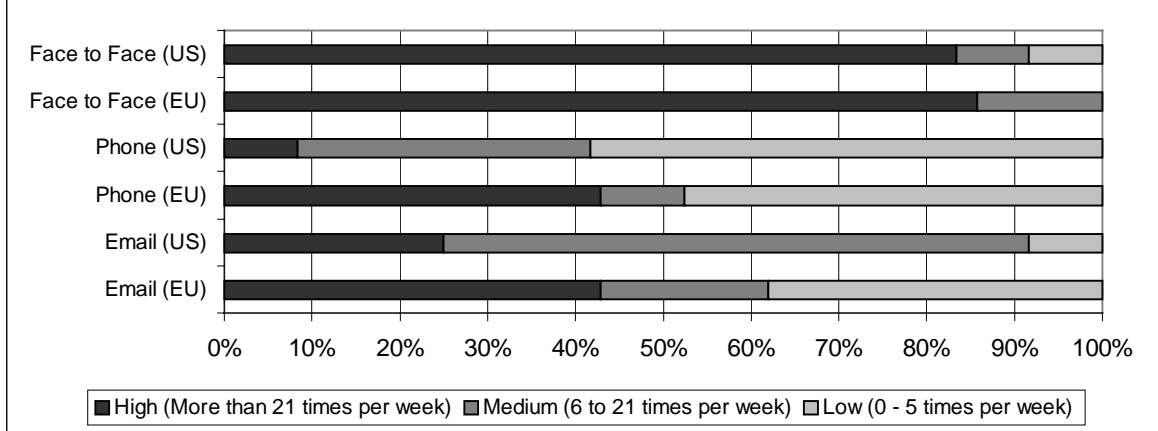


Figure 1.2: Total frequency of communication with co-workers

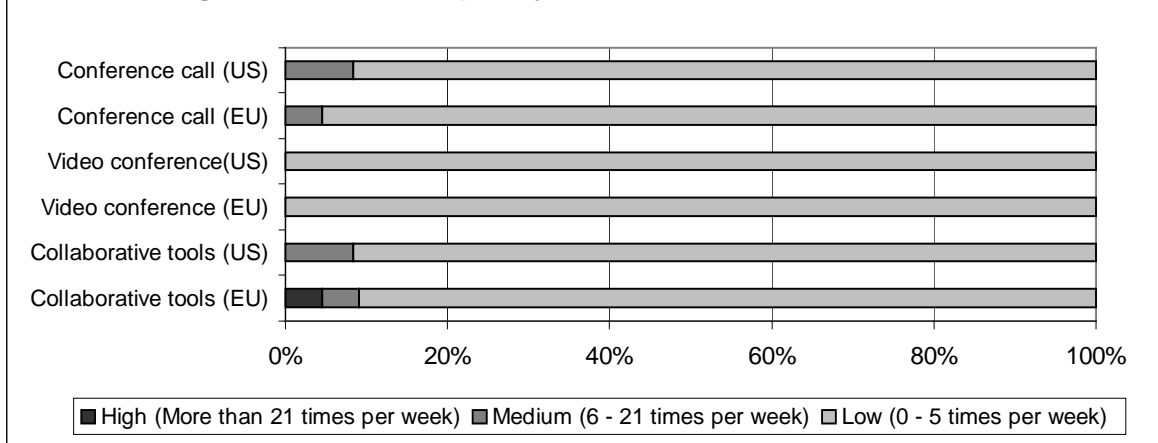


Figure 1.3: Frequency of communication with remote sites

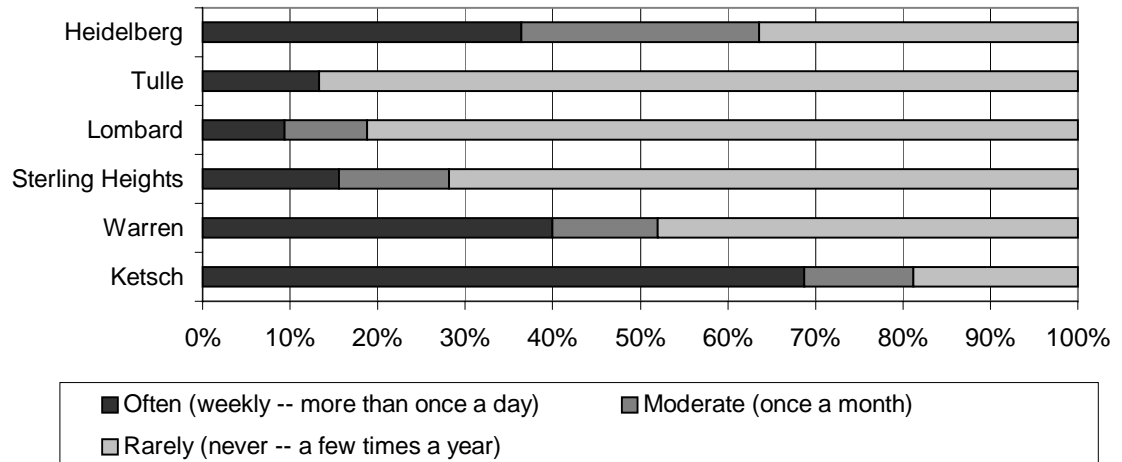


Figure 1.4: Travel to other sites

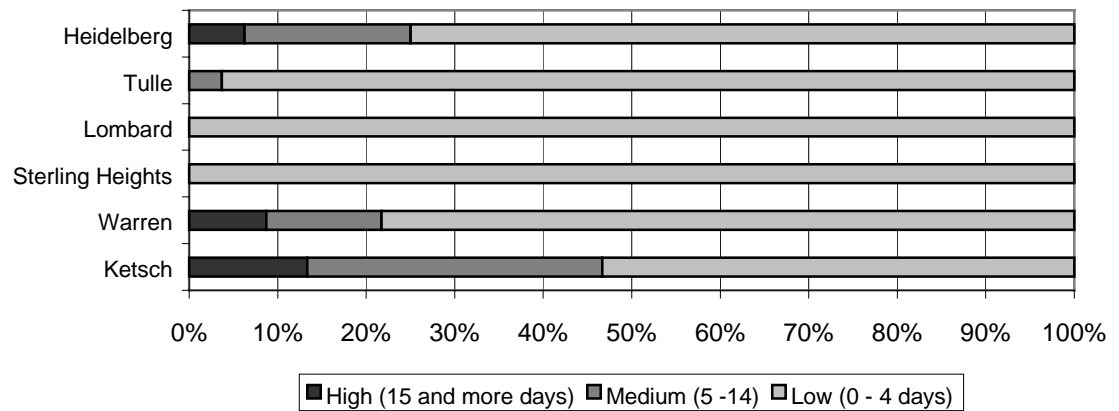


Figure 1.5: Differences in technology adoption (US and EU)

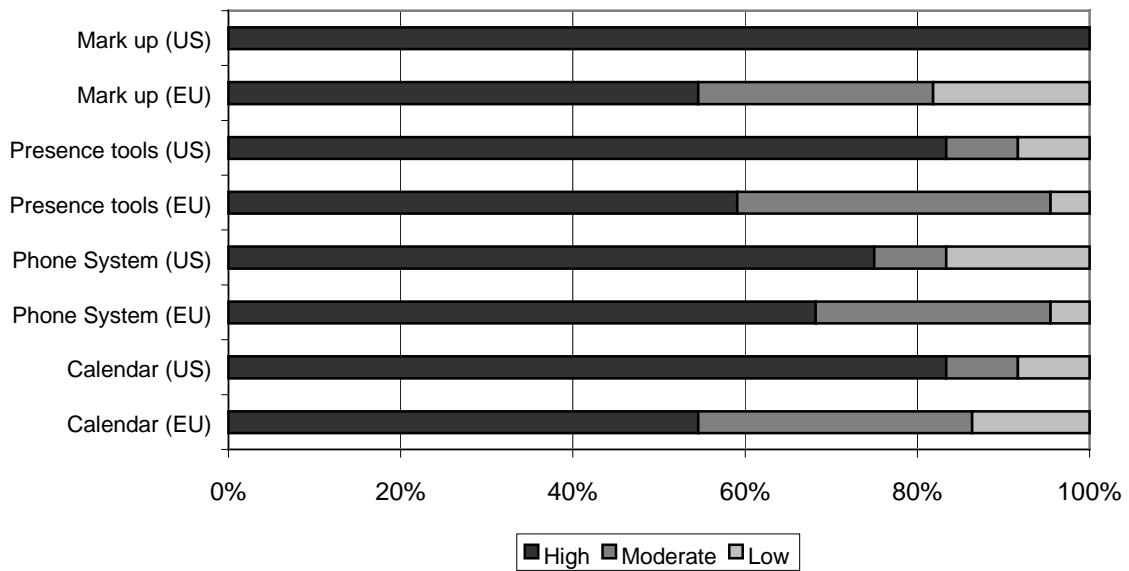


Figure 1.6: Work Flow

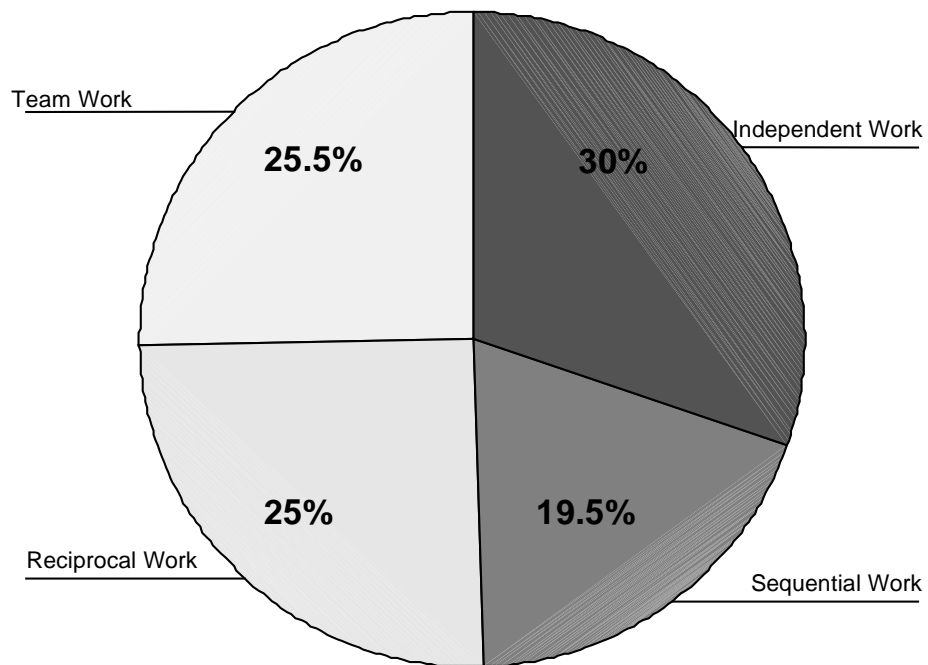


Figure 1.7: Group Identification

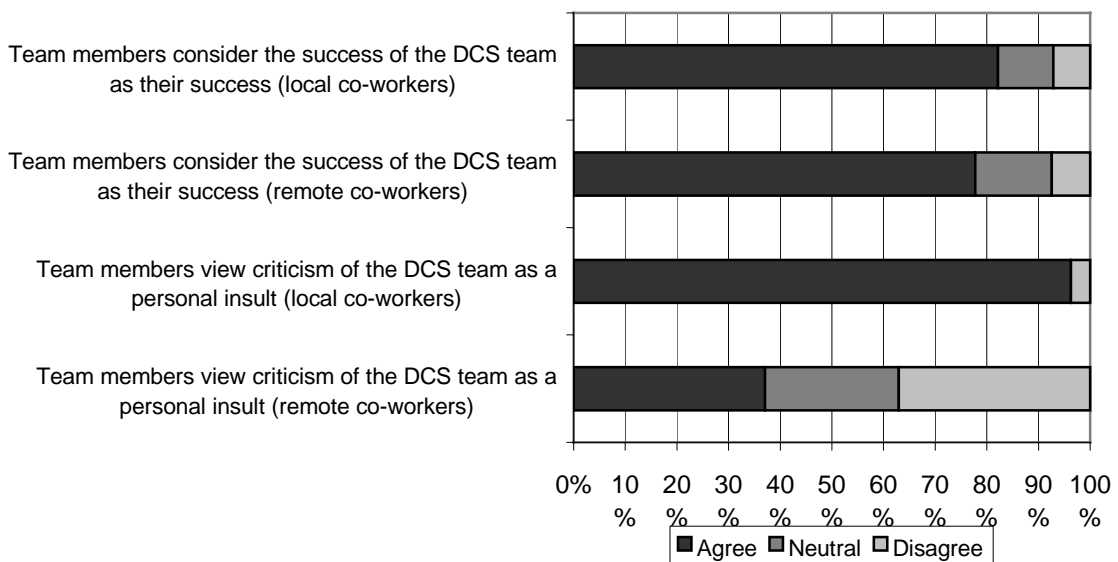


Figure 1.8: Trust in local and remote co-workers

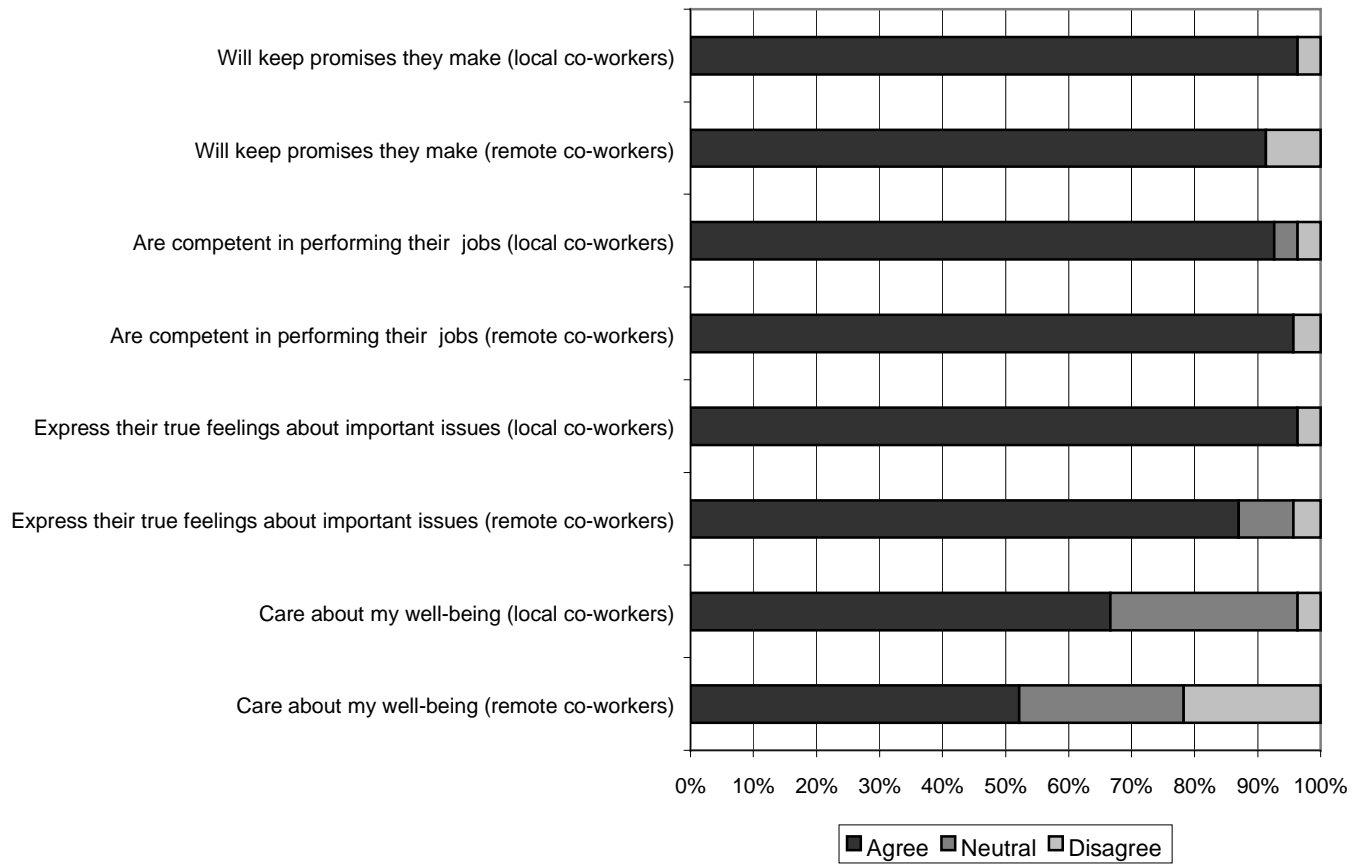


Figure 1.9: Trust in local and remote coworkers, cont.

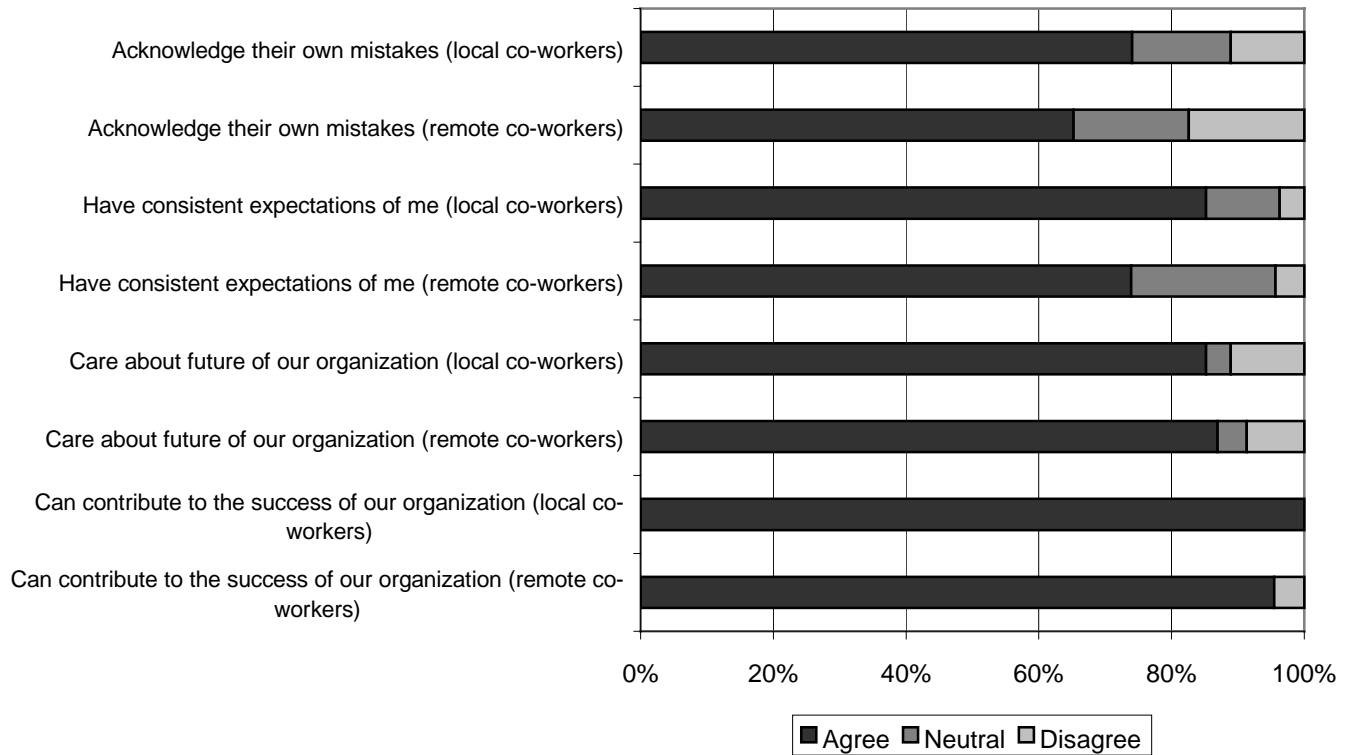


Figure 1.10: Organizational citizenship

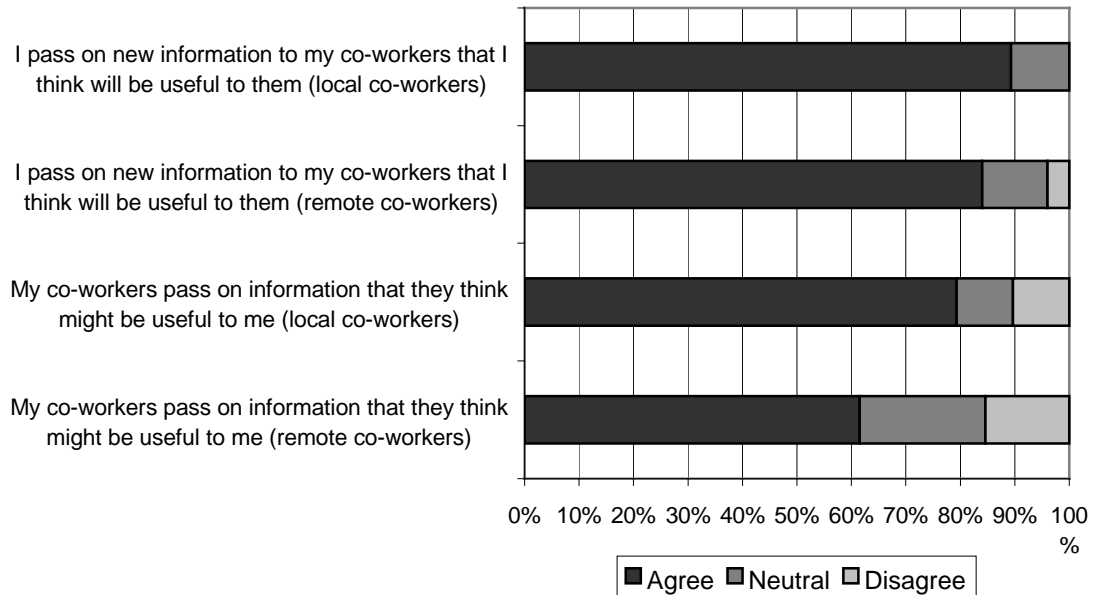


Figure 1.11: Coordinating work with local and remote co-workers

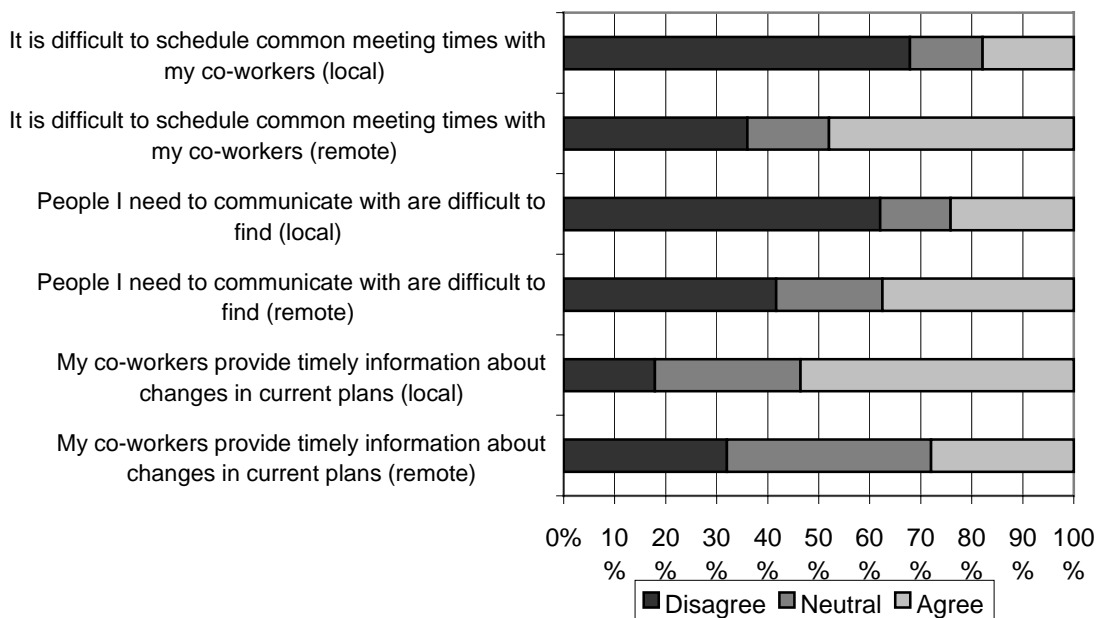


Figure 1.12: Frequency of delays in work

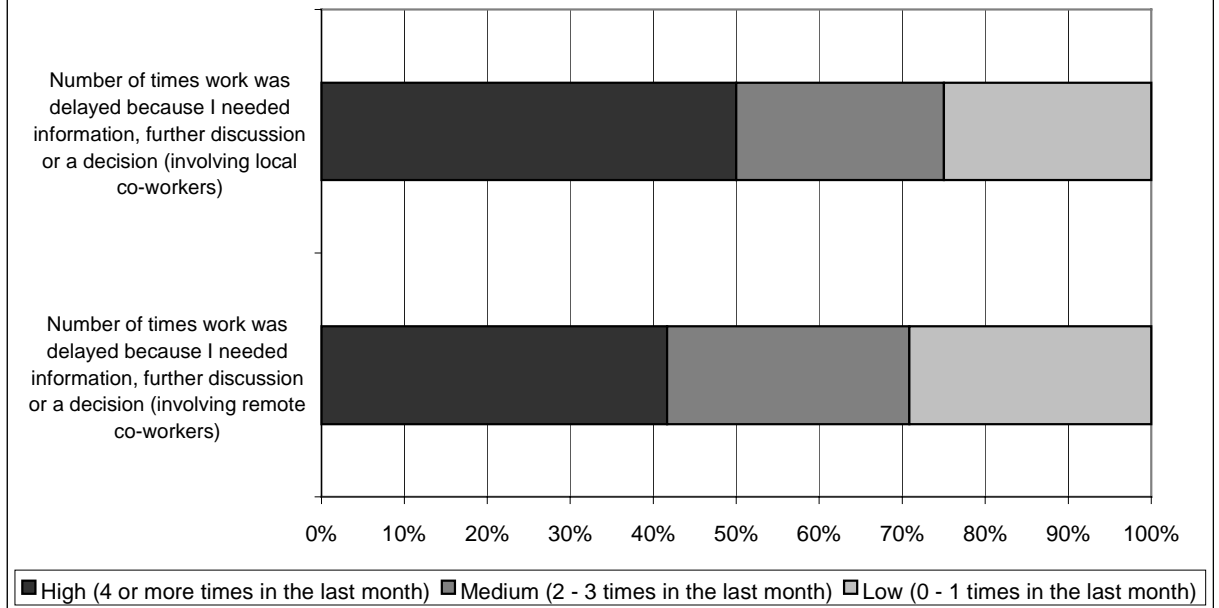


Figure 1.13: Average length of delays in work

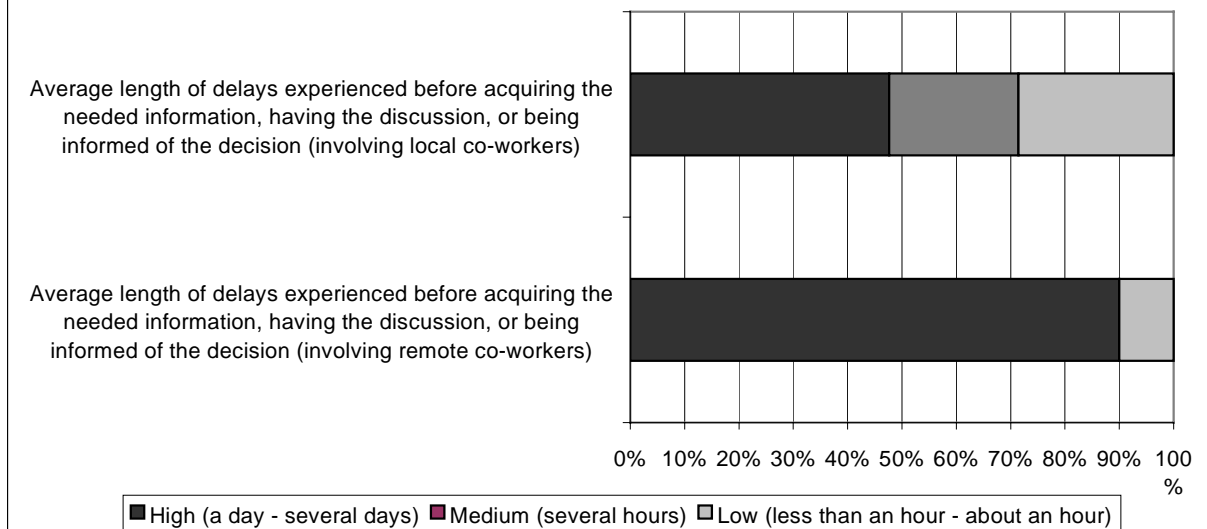


Figure 2.1: Total frequency of work-related communication

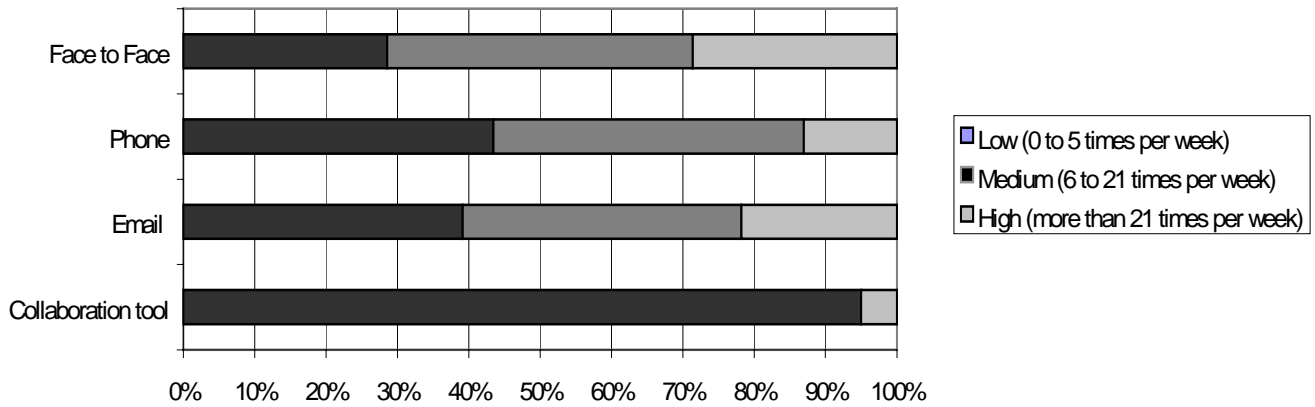


Figure 2.2: Frequency of communication by location

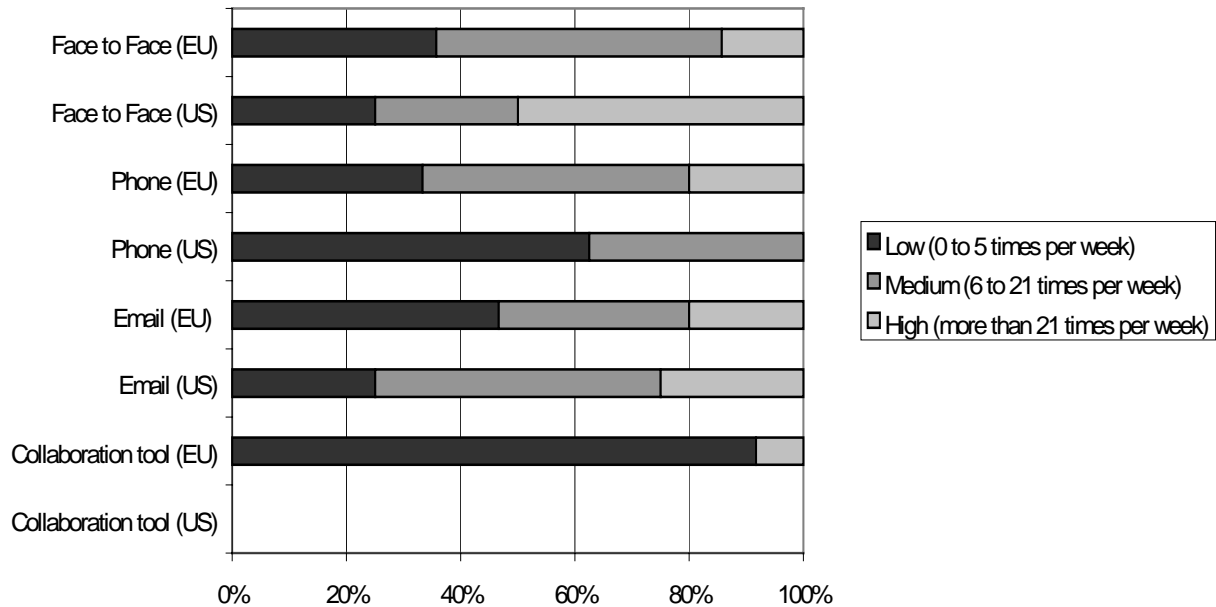


Figure 2.3: Frequency of communication with other sites

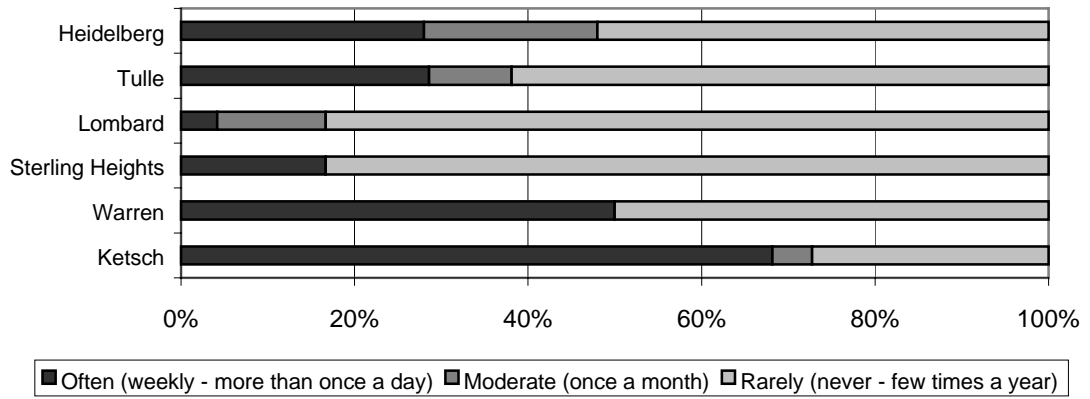


Figure 2.4: Travel to other sites

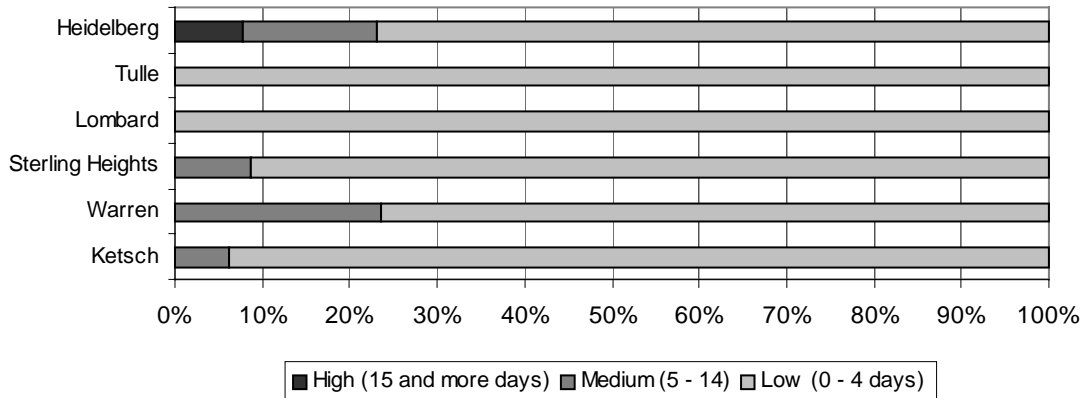


Figure 2.5: Frequency of non-work communication

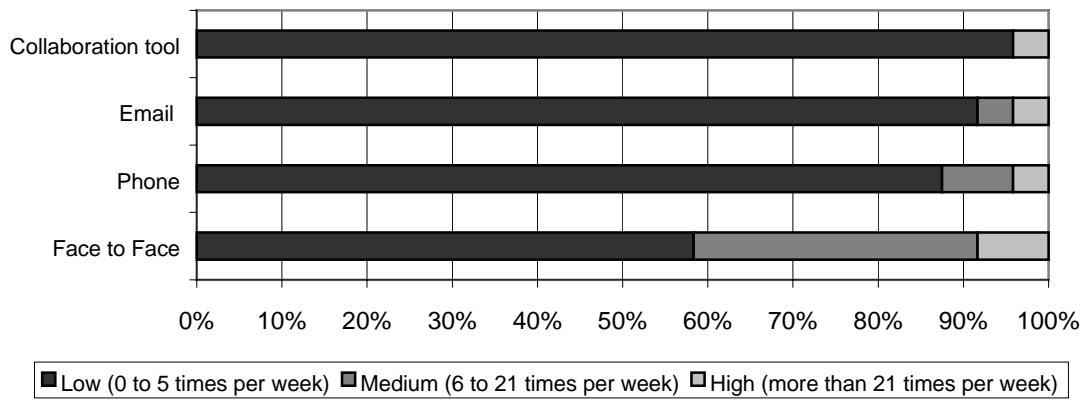


Figure 2.6: Differences in technology adoption

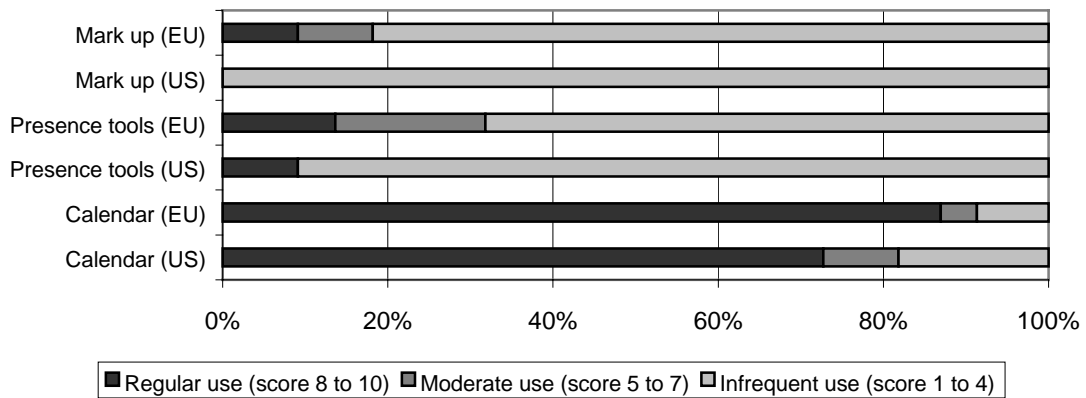


Figure 2.7: Collaborative tool impact on the design process

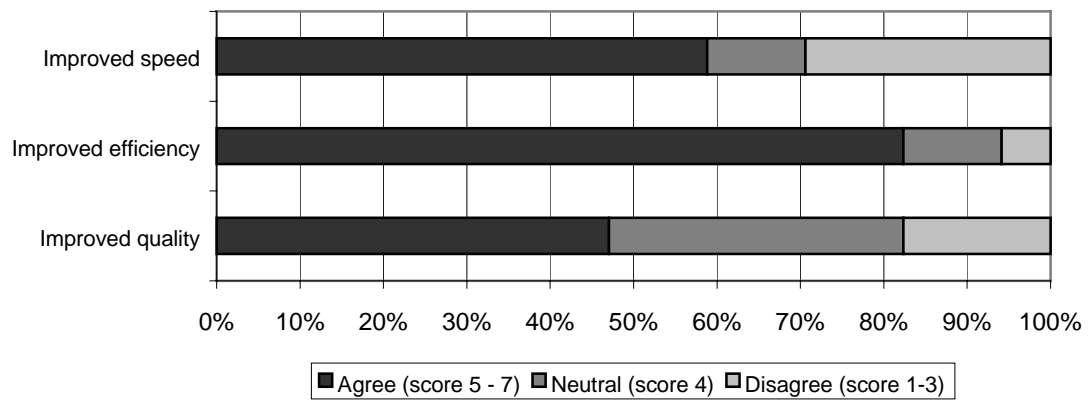


Figure 2.8. Overall type of workflow

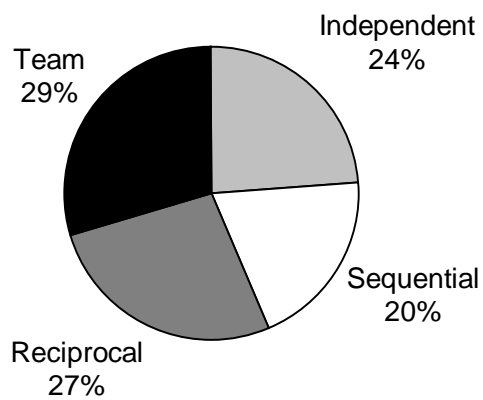


Figure 2.9: Trust in local and remote coworkers

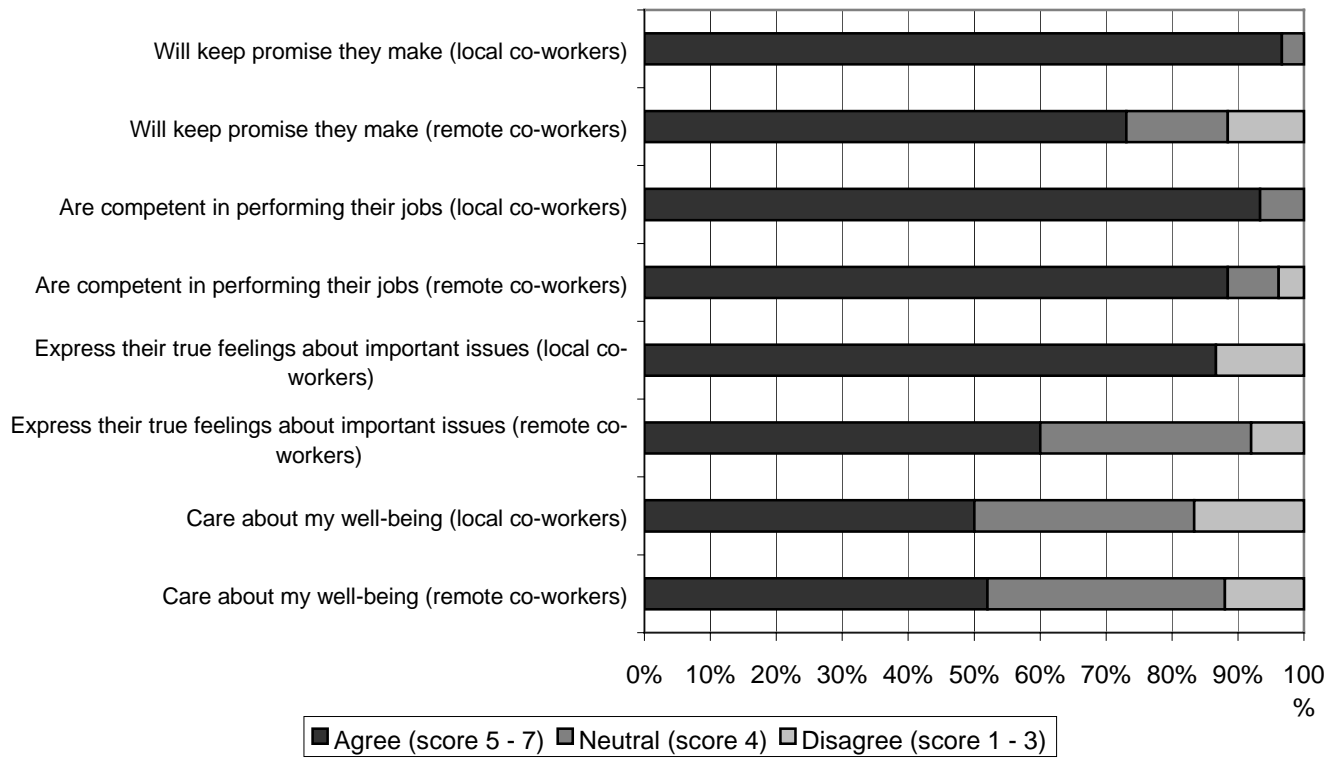


Figure 2.10: Trust in local and remote coworkers, cont.

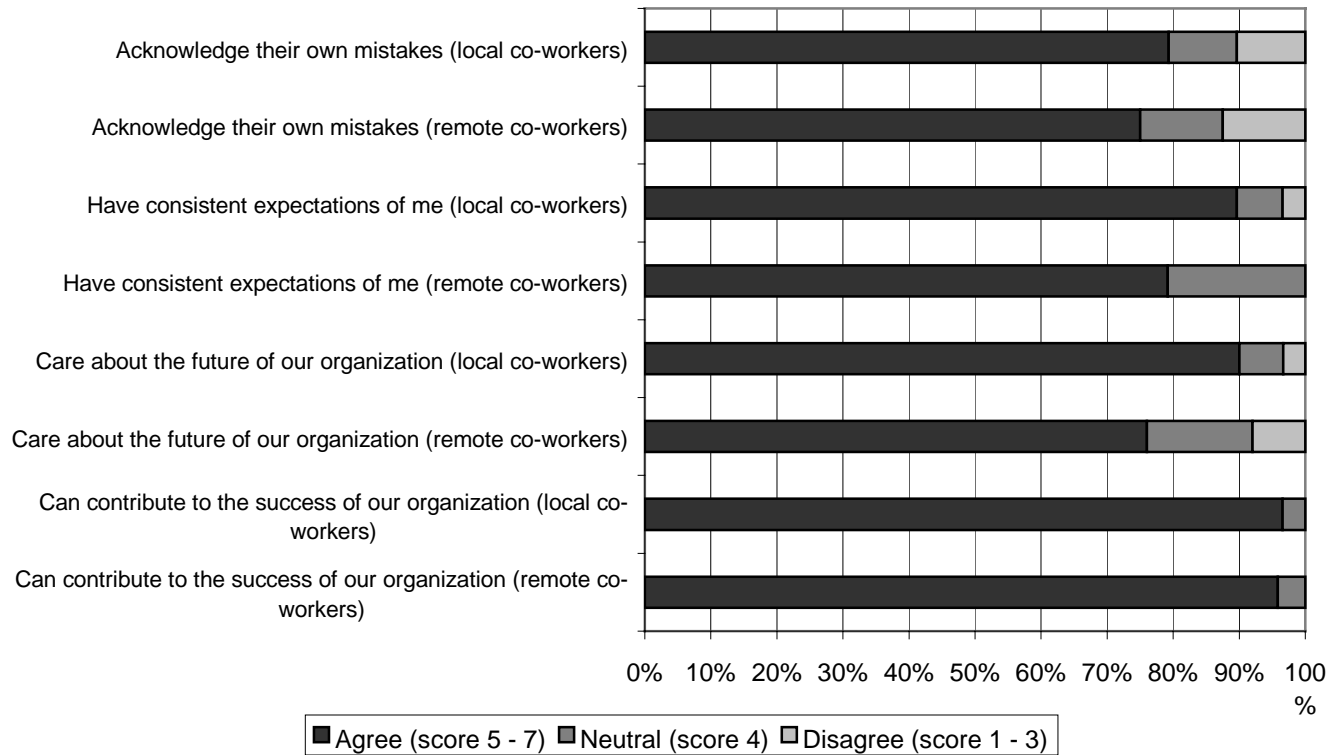


Figure 2.11: Coordinating work with local and remote co-workers

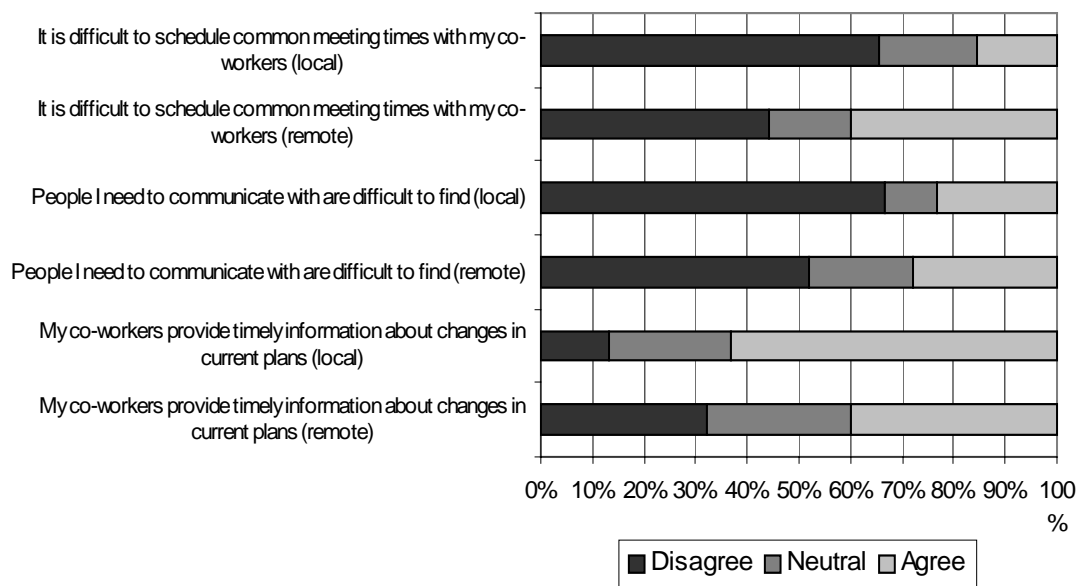


Figure 2.12: Frequency of delays in work

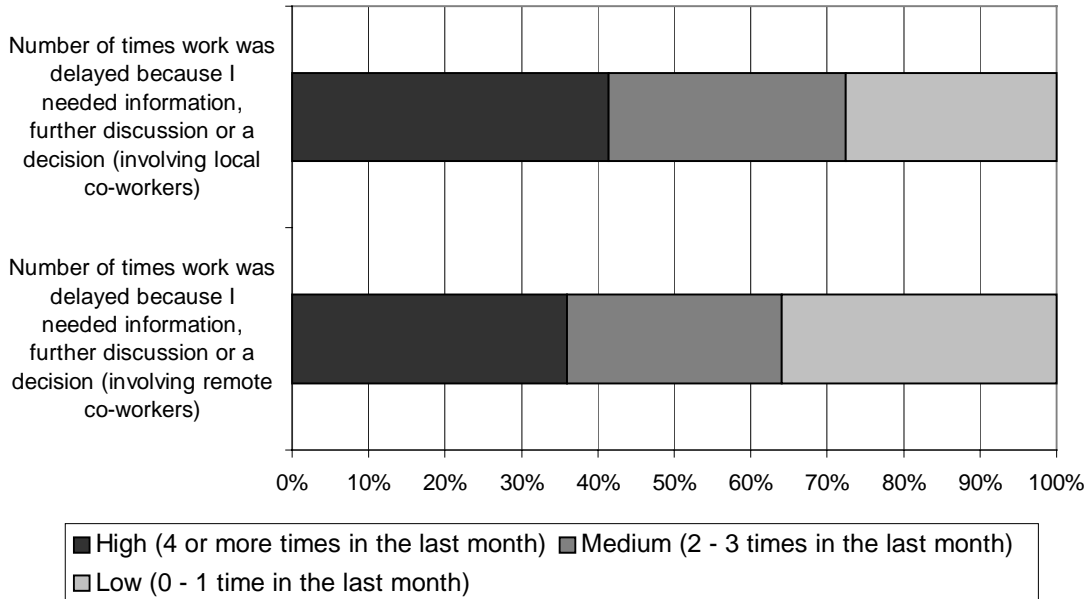


Figure 2.13: Average length of delays in work

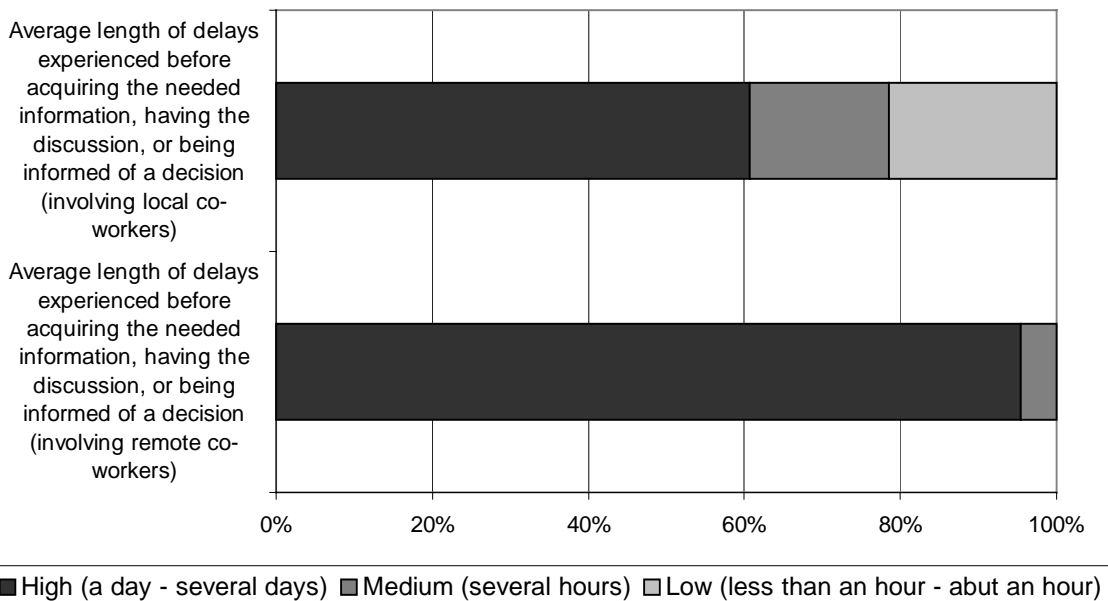
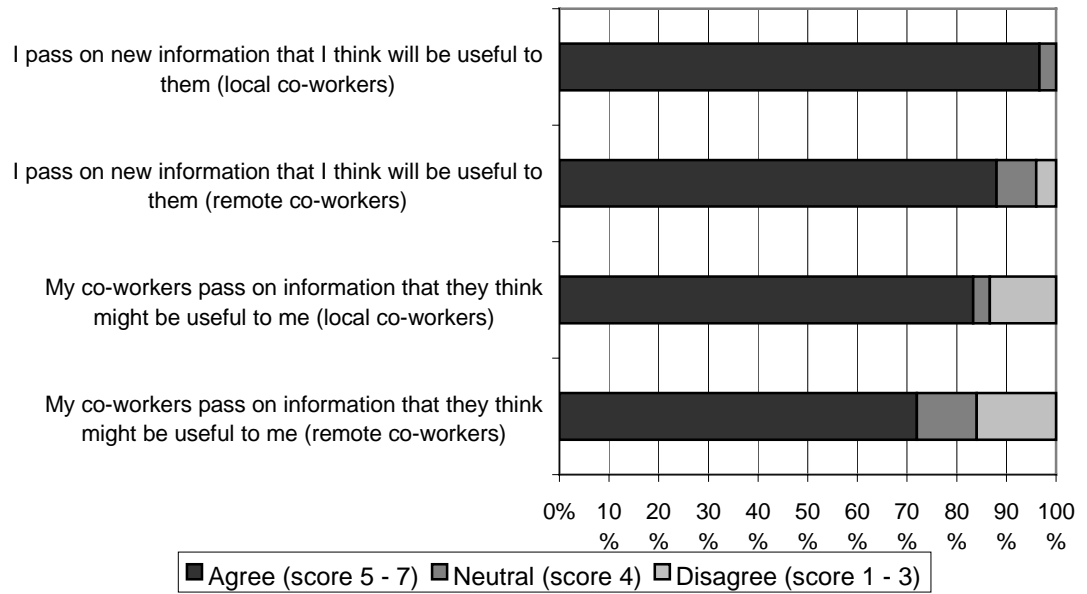


Figure 2.14: Organizational citizenship



APPENDIX F: DISTRIBUTION TABLE

Table 1. Sample distribution for survey 1 and survey 2.

Location	Number of respondents at Time 1		Number of respondents at Time 2	
	<i>Potential</i>	<i>Actual</i>	<i>Potential</i>	<i>Actual</i>
United States	17	12	22 (11 repeat)	11 (3 repeat)
Europe	34	22	39 (32 repeat)	23 (13 repeat)

APPENDIX G: CORRELATION TABLES TIME 1

Table 2. Dependent variables correlated with one another.

Variables	1	2	3	4	5	6	7	8
1. Local meeting scheduling difficulties	---							
2. Distant meeting scheduling difficulties	.61 ^{5**}	---						
3. Local timely information about changes	.12 ²	-.21 ⁵	---					
4. Distant timely information about changes	.09 ⁵	-.11 ⁵	.74 ^{5*}	---				
5. Local difficulty in finding people	.65 ^{2**}	.59 ^{5**}	.01 ²	.25 ⁵	---			
6. Distant difficulty in finding people	.62 ^{6**}	.58 ^{6**}	.18 ⁶	.20 ⁶	.79 ^{6**}	---		
7. Local information passing	.28 ²	-.04 ⁵	.62 ^{2**}	.52 ^{5**}	.35 ¹	.32 ⁶	---	
8. Distant information passing	.33 ⁵	.08 ⁵	.69 ^{5**}	.66 ^{5**}	.45 ^{5*}	.34 ⁶	.84 ^{5**}	---
9. Local information receiving	-.01 ³	-.15 ⁶	.42 ^{3*}	.22 ⁶	.23 ²	.25 ⁶	.72 ^{2**}	.51 ^{6*}
10. Distant information receiving	.07 ⁵	-.21 ⁵	.33 ⁵	.28 ⁵	.31 ⁵	.32 ⁶	.42 ^{5*}	.27 ⁵
11. Delay due to local co-workers	-.34 ⁷	-.08 ⁹	-.32 ⁸	-.16 ⁹	-.21 ⁷	-.15 ¹⁰	-.35 ⁸	-.20 ⁹
12. Delay due to distant co-workers	-.34 ⁸	-.44 ^{8*}	-.15 ⁸	-.13 ⁸	-.36 ⁸	-.56 ^{9**}	-.18 ⁸	-.21 ⁸
13. Length of delay due to local co-workers	.29 ⁸	.29 ¹⁰	.30 ⁹	.35 ¹⁰	.27 ⁸	.30 ¹¹	.12 ⁸	.41 ¹⁰
14. Length of delay due to distant co-workers	.19 ¹²	.53 ^{12*}	.13 ¹²	.28 ¹²	.25 ¹²	.46 ¹³	-.01 ¹²	.11 ¹²
15. Average local trust	.14 ⁴	-.10 ⁶	.36 ³	.20 ⁶	.22 ³	.35 ⁷	.26 ³	.38 ⁶
16. Average distant trust	.24 ⁷	-.11 ⁷	.59 ^{7**}	.50 ^{7*}	.29 ⁷	.31 ⁸	.50 ⁷	.60 ^{7**}
17. Average total trust	.10 ⁴	-.25 ⁶	.21 ³	.52 ^{6**}	.36 ³	.29 ⁷	.45 ^{3*}	.51 ^{6*}

Note. The statistic reported here is Pearson's r. The superscript * symbol indicates the level of significance of the correlation, and the superscript numbers indicate the sample size. Legend follows below.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

¹.n = 29, ².n = 28, ³.n = 27, ⁴.n = 26, ⁵.n = 25, ⁶.n = 24, ⁷.n = 23, ⁸.n = 22, ⁹.n = 21, ¹⁰.n = 20, ¹¹.n = 19, ¹².n = 18, ¹³.n = 17.

Table 3. Dependent variables correlated with one another, continued.

Variables	9	10	11	12	13	14	15	16	17
9. Local information receiving	- - -								
10. Distant information receiving	.846**	- - -							
11. Delay due to local co-workers	.01 ⁸	.12 ⁵	- - -						
12. Delay due to distant co-workers	.13 ⁹	.31 ⁸	.31 ⁸	- - -					
13. Length of delay due to local co-workers	.11 ⁹	.32 ¹⁰	.32 ⁸	-.05 ¹⁰	- - -				
14. Length of delay due to distant co-workers	-.10 ¹³	-.02 ¹⁰	-.06 ¹²	-.41 ¹¹	.34 ¹²	- - -			
15. Average local trust	.23 ⁴	.22 ⁶	-.29 ⁸	-.53 ^{8*}	.35 ¹⁰	.46 ¹³	- - -		
16. Average distant trust	.37 ⁸	.34 ⁷	-.14 ⁹	-.36 ⁸	.37 ¹¹	.28 ¹³	.817**	- - -	
17. Average total trust	.27 ⁴	.31 ⁶	-.22 ⁸	-.48 ^{8*}	.04 ¹⁰	.40 ¹³	.603**	.967**	- - -

Note. The statistic reported here is Pearson's *r*. The superscript * symbol indicates the level of significance of the correlation, and the superscript numbers indicate the sample size. Legend follows below.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

¹.n = 29, ².n = 28, ³.n = 27, ⁴.n = 26, ⁵.n = 25, ⁶.n = 24, ⁷.n = 23, ⁸.n = 22, ⁹.n = 21, ¹⁰.n = 20, ¹¹.n = 19,

¹².n = 18, ¹³.n = 17.

APPENDIX H: CORRELATION TABLES TIME 2

Table 4. Dependent variables correlated with one another, variables 1 - 11.

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Change in design process	---										
2. Quality improvement	0.1 ⁵	---									
3. Efficiency improvement	0.1 ⁵	0.51 ^{5*}	---								
4. Speed improvement	0.07 ⁵	0.33 ¹	0.68 ^{1**}	---							
5. Local meeting scheduling difficulties	0.12 ¹¹	-0.28 ⁴	0.17 ⁴	0.22 ⁴	---						
6. Distant meeting scheduling difficulties	0.11 ⁸	-0.17 ²	0.11 ²	0.41 ²	0.73 ^{9**}	---					
7. Local timely information about changes	0.36 ¹¹	-0.13 ⁴	-0.4 ⁴	-0.32 ⁴	0.27 ¹³	0.28 ⁹	---				
8. Distant timely information about changes	0.02 ⁸	0.26 ²	0.72 ^{2*}	0.66 ^{2*}	0.49 [*]	0.21 ⁹	0.64 ^{9**}	---			
9. Local difficulty in finding people	-0.07 ¹¹	-0.12 ⁴	-0.25 ⁴	-0.01 ⁴	0.02 ¹³	0.35 ⁹	0.16 ¹³	0.10 ⁹	---		
10. Distant difficulty in finding people	-0.04 ⁸	0.02 ²	-0.14 ²	-0.02 ²	0.18 ⁹	0.25 ⁹	0.29 ⁹	0.21 ⁹	0.84 ^{9**}	---	
11. Local information passing	-0.06 ¹¹	0.0 ⁴	0.1 ⁴	-0.1 ⁴	0.23 ¹³	0.05 ⁹	0.13 ¹³	0.31 ⁹	0.11 ¹³	0.12 ⁹	---

Note. The statistic reported here is Pearson's r . The superscript * symbol indicates the level of significance of the correlation, and the superscript numbers indicate the sample size. Legend follows below.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

¹.N = 10, ². N = 11, ³. N = 12, ⁴. N = 13, ⁵. N = 17, ⁶. N = 22, ⁷. N = 23, ⁸. N = 24, ⁹. N = 25, ¹⁰. N = 26, ¹¹.N = 28, ¹².N = 29, ¹³.N = 30.

Table 5. Dependent variables correlated with one another, variables 1 - 12 and 12 - 21.

Variables	1	2	3	4	5	6	7	8	9	10	11	12
12. Distant information passing	-0.13 ⁸	0.15 ²	0.45 ²	0.24 ²	0.54 ^{9**}	0.28 ⁹	0.25 ⁹	0.4 ^{9*}	0.16 ⁹	0.3 ⁹	0.59 ^{9**}	- - -
13. Local information receiving	-0.01 ¹¹	-0.12 ⁴	-0.11 ⁴	-0.03 ⁴	0.53 ^{13**}	0.35 ⁹	0.46 ^{13*}	0.33 ⁹	0.27 ¹³	0.37 ⁹	0.36 ¹³	0.61 ^{9**}
14. Distant information receiving	0.04 ⁸	-0.04 ²	0.03 ²	0.24 ²	.46 ^{9*}	0.36 ⁹	0.37 ⁹	0.43 ^{9*}	.47 ^{9*}	0.61 ^{9**}	0.21 ⁹	0.61 ^{9**}
15. Delay due to local co-workers	-0.001 ¹⁰	0.02 ³	-0.49 ³	-0.33 ³	-0.25 ¹²	-0.09 ⁹	-0.1 ¹²	-0.17 ⁹	-0.1 ¹²	-0.33 ⁹	0.12 ¹²	-0.33 ⁹
16. Delay due to distant co-workers	0.47 ^{8*}	-0.14 ²	-.67 ^{2*}	-0.58 ²	0.03 ⁹	0.11 ⁹	0.17 ⁹	-0.32 ⁹	-0.22 ⁹	0.36 ⁹	-0.13 ⁹	-0.08 ⁹
17. Length of delay due to local co-workers	-0.18 ¹⁰	-.68 ^{3*}	-0.02 ³	-0.14 ³	0.40 ^{11*}	0.25 ⁷	0.47 ^{11*}	0.49 ^{7*}	0.3 ¹¹	0.28 ⁷	-0.08 ¹¹	0.22 ⁷
18. Length of delay due to distant co-workers	-0.37 ⁶	-0.45 ¹	-0.1 ¹	0.11 ¹	0.20 ⁶	0.10 ⁶	0.4 ⁶	0.44 ^{6*}	.45 ^{6*}	0.44 ^{6*}	0.32 ⁶	0.16 ⁶
19. Average local trust	0.2 ¹¹	0.07 ⁴	0.02 ⁴	0.37 ⁴	0.48 ^{13**}	0.29 ⁹	0.65 ^{13**}	0.63 ^{9**}	0.22 ¹³	0.49 ^{9*}	0.11 ¹³	0.32 ⁹
20. Average distant trust	0.15 ⁸	0.24 ²	0.382 ²	0.73 ^{2*}	0.62 ^{10*}	0.29 ⁹	0.51 ^{10**}	0.73 ^{9**}	0.19 ¹⁰	0.55 ^{9**}	0.25 ¹⁰	0.53 ^{9**}
21. Average total trust	0.21 ¹¹	0.55 ⁴	0.371 ⁴	0.64 ^{4*}	0.44 ^{13*}	0.31 ⁹	0.35 ¹³	0.73 ^{9**}	-0.04 ¹³	0.56 ^{9**}	0.06 ¹³	0.46 ^{9*}

Note. The statistic reported here is Pearson's *r*. The superscript * symbol indicates the level of significance of the correlation, and the superscript numbers indicate the sample size. Legend follows below.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

¹.N = 10, ². N = 11, ³. N = 12, ⁴. N = 13, ⁵. N = 17, ⁶. N = 22, ⁷. N = 23, ⁸. N = 24, ⁹. N = 25, ¹⁰. N = 26, ¹¹.N = 28, ¹².N = 29, ¹³.N = 30.

Table 6. Dependent variables correlated with one another, variables 13 - 21.

Variables	13	14	15	16	17	18	19	20	21
13. Local information receiving	---								
14. Distant information receiving	0.79 ^{9**}	---							
15. Delay due to local co-workers	-0.16 ¹²	-0.21 ⁹	---						
16. Delay due to distant co-workers	0.04 ⁹	-0.06 ⁹	0.72 ^{9**}	---					
17. Length of delay due to local co-workers	0.35 ¹¹	0.33 ⁷	-.43 ^{10*}	-0.28 ⁷	---				
18. Length of delay due to distant co-workers	0.2 ⁶	0.2 ⁶	-0.26 ⁶	-0.41 ⁶	0.62 ^{6**}	---			
19. Average local trust	0.56 ^{13**}	0.56 ^{9**}	-.43 ^{12*}	-0.21 ⁹	0.51 ^{11**}	0.49 ^{6*}	---		
20. Average distant trust	0.43 ^{10*}	0.62 ^{9**}	-0.21 ¹⁰	-0.23 ⁹	0.36 ⁸	0.48 ^{6*}	0.77 ^{10**}	---	
21. Average total trust	0.38 ^{13*}	0.63 ^{9**}	-0.49 ^{12**}	-0.23 ⁹	0.17 ¹¹	0.56 [*]	0.75 ^{13**}	0.96 ^{10**}	---

Note. The statistic reported here is Pearson's r . The superscript * symbol indicates the level of significance of the correlation, and the superscript numbers indicate the sample size. Legend follows below.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

¹.N = 10, ². N = 11, ³. N = 12, ⁴. N = 13, ⁵. N = 17, ⁶. N = 22, ⁷. N = 23, ⁸. N = 24, ⁹. N = 25, ¹⁰. N = 26, ¹¹.N = 28, ¹².N = 29, ¹³.N = 30.

Table 7. Time 2 communication variables correlated with dependent variables

Variables	22. Weekly frequency of face-to-face communication with local co-workers	23. Number of coworkers communicate with daily (local)	24. Number of coworkers communicate with daily (distant)
1. Change in design process	.19 ¹¹	.39 ^{12*}	.47 ^{8*}
2. Quality improvement	-.12 ⁴	.20 ⁵	.10 ⁵
3. Efficiency improvement	.42 ⁴	.03 ⁵	-.05 ⁵
4. Speed improvement	.33 ⁴	-.03 ⁵	-.33 ⁵
5. Local meeting scheduling difficulties	.09 ¹²	-.35 ¹²	-.21 ⁸
6. Distant meeting scheduling difficulties	.08 ⁹	-.13 ⁸	.13 ⁶
7. Local timely information about changes	.31 ¹²	.43 ^{12*}	.27 ⁸
8. Distant timely information about changes	.31 ⁹	.10 ⁸	-.09 ⁶
9. Local difficulty in finding people	.15 ¹²	.07 ¹²	.18 ⁸
10. Distant difficulty in finding people	.19 ⁹	.16 ⁸	.17 ⁶
11. Local information passing	.30 ¹²	-.01 ¹²	.14 ⁸
12. Distant information passing	.23 ⁹	.06 ⁸	.20 ⁶
13. Local information receiving	.11 ¹²	-.03 ¹²	.12 ⁸
14. Distant information receiving	.22 ⁹	-.20 ⁸	.15 ⁶
15. Delay due to local co-workers	-.13 ¹¹	.15 ¹¹	-.05 ⁷
16. Delay due to distant co-workers	-.17 ⁹	.06 ⁸	.17 ⁶
17. Length of delay due to local co-workers	.22 ¹¹	-.20 ¹¹	-.36 ⁶
18. Length of delay due to distant co-workers	.44 ^{6*}	-.01 ⁶	-.26 ⁶
19. Average local trust	.23 ¹²	.26 ¹²	-.10 ⁸
20. Average distant trust	.24 ¹⁰	.11 ⁹	-.18 ⁷
21. Average total trust	.19 ¹²	.03 ¹²	-.15 ⁸
22. Weekly frequency of face-to-face communication with local co-workers	- - -	- - -	- - -
23. Number of coworkers communicate with daily (local)	.27 ¹²	- - -	- - -
24. Number of coworkers communicate with daily (distant)	.14 ⁹	.56 ^{10**}	- - -

Note. The statistic reported here is Pearson's *r*. The superscript * symbol indicates the level of significance of the correlation, and the superscript numbers indicate the sample size. Legend follows below.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

¹.N = 10, ². N = 11, ³. N = 12, ⁴. N = 13, ⁵. N = 17, ⁶. N = 22, ⁷. N = 23, ⁸. N = 24, ⁹. N = 25, ¹⁰. N = 26, ¹¹.N = 28, ¹².N = 29, ¹³.N = 30, ¹⁴.N = 30.

APPENDIX I: T-TEST TABLES

Table 8. Comparison of variables between survey 1 and survey 2 using paired T-tests

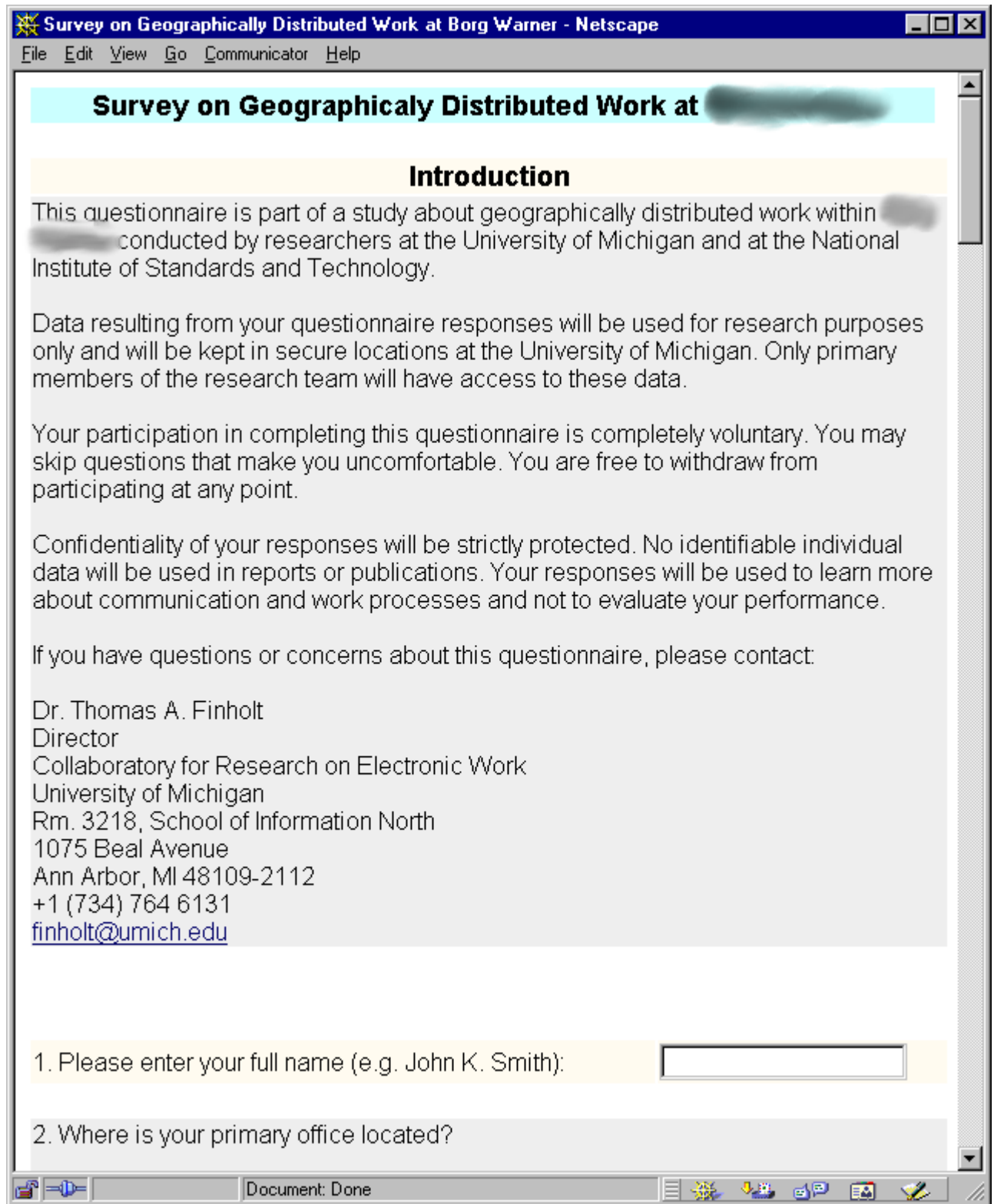
Variable	Mean 1	Mean 2	Sig	df
Workflow				
Independent work flow	32.50	21.25	p < 0.01	15
Sequential work flow	18.13	18.44	n.s	15
Reciprocal work flow	22.81	25.00	n.s	15
Team work flow	26.56	35.31	n.s	15
Communication				
Total days spent at distant sites	17.92	12.25	n.s	11
Frequency of communication with distant sites	7.27	8.87	n.s	14
Coordination				
Difficulty of scheduling common meeting times with local co-workers	5.25	5.50	n.s	11
Difficulty of scheduling common meeting times with distant co-workers	4.40	5.20	n.s	9
Receiving timely information from local co-workers about changes in current plans	4.25	4.83	n.s	11
Receiving timely information from distant co-workers about changes in current plans	3.30	4.20	n.s	9
Difficulty in finding local co-workers	4.92	4.92	n.s	11
Difficulty in finding distant co-workers	4.44	4.00	n.s	8
Organizational citizenship				
Passing new information to local co-workers	5.55	6.18	n.s	10
Passing new information to distant co-workers	5.20	5.60	n.s	9
Local co-workers passing information	5.08	5.25	n.s	11
Distant co-workers passing information	4.90	4.90	n.s	9
Performance				
Delay in work involving local co-workers	4.64	6.82	n.s	10
Delay in work involving distant co-workers	4.33	5.78	n.s	8
Length of delay involving local co-workers	2.80	2.20	n.s	9
Length of delay involving distant co-workers	2.00	1.29	n.s	6
Trust				
Trust in local co-workers	5.86	5.51	n.s	11
Trust in distant co-workers	5.15	5.31	n.s	8
Total trust	10.30	9.93	n.s	11

Table 9. Comparison of variables between survey 1 and survey 2 using independent sample t-tests (equal variances not assumed)

Variable	Mean 1	Mean 2	Sig	df
Workflow				
Independent work flow	30.15	23.26	n.s.	62.71
Sequential work flow	19.28	19.12	n.s.	63.96
Reciprocal work flow	25.16	26.18	n.s.	60.12
Team work flow	25.41	28.82	n.s.	62.28
Communication				
Total days spent at distant sites	17.75	8.19	n.s.	53.29
Frequency of communication with distant sites	6.84	7.31	n.s.	47.86
Coordination				
Difficulty of scheduling common meeting times with local co-workers	4.86	4.33	n.s.	58.09
Difficulty of scheduling common meeting times with distant co-workers	3.68	3.21	n.s.	55.97
Receiving timely information from local co-workers about changes in current plans	4.57	4.41	n.s.	59.37
Receiving timely information from distant co-workers about changes in current plans	3.88	3.12	n.s.	56.69
Difficulty in finding local co-workers	4.72	4.47	n.s.	56.39
Difficulty in finding distant co-workers	4.08	3.38	n.s.	54.10
Organizational citizenship				
Passing new information to local co-workers	5.79	5.41	n.s.	46.92
Passing new information to distant co-workers	5.60	4.15	p < .01	45.52
Local co-workers passing information	5.41	4.74	n.s.	54.05
Distant co-workers passing information	5.16	3.71	p < .01	55.52
Performance				
Delay in work involving local co-workers	4.25	4.93	n.s.	46.84
Delay in work involving distant co-workers	3.87	5.84	n.s.	33.63
Length of delay involving local co-workers	2.65	1.97	p < .10	51.36
Length of delay involving distant co-workers	1.80	.91	p < .01	29.90
Trust				
Trust in local co-workers	5.72	5.63	n.s.	54.90
Trust in distant co-workers	5.41	5.41	n.s.	46.95
Total trust	10.33	10.32	n.s.	54.78

APPENDIX J: SURVEY INSTRUMENT, TIME 2

Note: All corporate, team, and individual identifying information has been deliberately obscured.



The screenshot shows a Netscape browser window with the title bar 'Survey on Geographically Distributed Work at Borg Warner - Netscape'. The menu bar includes 'File', 'Edit', 'View', 'Go', 'Communicator', and 'Help'. The main content area has a light blue header with the title 'Survey on Geographically Distributed Work at [redacted]'. Below this is a yellow section titled 'Introduction'. The text in the introduction states that the questionnaire is part of a study about geographically distributed work within [redacted], conducted by researchers at the University of Michigan and at the National Institute of Standards and Technology. It explains that data will be used for research purposes only, kept secure at the University of Michigan, and that participation is voluntary. It also mentions that confidentiality will be strictly protected. At the end of the introduction, it provides contact information for Dr. Thomas A. Finholt, Director of the Collaboratory for Research on Electronic Work at the University of Michigan. The contact details include the address (Rm. 3218, School of Information North, 1075 Beal Avenue, Ann Arbor, MI 48109-2112), a phone number (+1 (734) 764 6131), and an email address (finholt@umich.edu). Below the introduction, there are two numbered questions. Question 1 asks for the full name (e.g., John K. Smith) and has a text input field. Question 2 asks where the primary office is located and has a text input field. The browser's status bar at the bottom shows 'Document: Done' and various icons.

Survey on Geographically Distributed Work at [redacted]

Introduction

This questionnaire is part of a study about geographically distributed work within [redacted] conducted by researchers at the University of Michigan and at the National Institute of Standards and Technology.

Data resulting from your questionnaire responses will be used for research purposes only and will be kept in secure locations at the University of Michigan. Only primary members of the research team will have access to these data.

Your participation in completing this questionnaire is completely voluntary. You may skip questions that make you uncomfortable. You are free to withdraw from participating at any point.

Confidentiality of your responses will be strictly protected. No identifiable individual data will be used in reports or publications. Your responses will be used to learn more about communication and work processes and not to evaluate your performance.

If you have questions or concerns about this questionnaire, please contact:

Dr. Thomas A. Finholt
Director
Collaboratory for Research on Electronic Work
University of Michigan
Rm. 3218, School of Information North
1075 Beal Avenue
Ann Arbor, MI 48109-2112
+1 (734) 764 6131
finholt@umich.edu

1. Please enter your full name (e.g. John K. Smith):

2. Where is your primary office located?

Survey on Geographically Distributed Work at Borg Warner - Netscape

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Please answer the following questions to the best of your ability using a 1 to 10 scale, with 10 being "regularly" and 1 being "not at all".

How often did you use the following collaborative tools in the last six months?	Scale from 1 to 10
3. An electronic calendar like Microsoft Outlook that lets you and your co-workers share information about your schedules?	<input type="text"/>
4. A presence awareness tool like ICQ that lets you and your co-workers share information about availability?	<input type="text"/>
5. An application sharing tool like NetMeeting that lets you and your co-workers simultaneously mark up a drawing when you are at your desks?	<input type="text"/>

6. Did the use of any of these collaborative tools change the manufacturing design process (i.e., the way you and your team went about working on the DCS project)?

☐ Yes ☐ No

If you answered "Yes," please answer the following questions:

Please comment on how the design tool(s) had an impact on the design process:

7. The use of these collaborative tools improved the *quality* of the product.

8. The use of these collaborative tools improved the *efficiency* of the design process.

9. The use of these collaborative tools improved the *speed* of the design process.

10. What is your job title?

11. On which project are you currently working (check all that apply)?

☐ ☐ ☐

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Survey on Geographically Distributed Work at Borg Warner - Netscape

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12. For your work on the _____ project, please indicate the percentage of your work that fits each of the following descriptions.

Type of Work Flow	Percentage of Work
a. INDEPENDENT work flow, where work and activities are performed by you and your co-workers independently and do not flow between you.	<input type="text"/>
b. SEQUENTIAL work flow, where work and activities flow between you and your co-workers in one direction	<input type="text"/>
c. RECIPROCAL work flow, where work and activities flow between you and your co-workers in a reciprocal "back and forth" manner over a period of time.	<input type="text"/>
d. TEAM work flow, where you and your co-workers diagnose, problem-solve and collaborate as a group at the SAME TIME to deal with the work	<input type="text"/>
Total = 100%	

Please think about your most important current project and the people involved. For the following questions, please provide two answers: first column (Local Co-workers) - in terms of your typical experience with co-workers at your site; and second column (Distant Co-workers) -- in terms of your typical experience with co-workers at the distant sites. For each question, please provide your best possible answer.

	Local Co-workers	Distant Co-workers
13. How many people work on this project?	<input type="text"/>	<input type="text"/>
14. How many co-workers on this project do you communicate with at least daily about non-work related matters?	<input type="text"/>	<input type="text"/>
15. How many co-workers on this project do you communicate with at least daily about work related matters?	<input type="text"/>	<input type="text"/>

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Survey on Geographically Distributed Work at Borg Warner - Netscape

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In a typical week, how many times do you communicate with co-workers on this project about non-work related matters:

16. face-to-face?	<input type="text"/>	<input type="text"/>
17. by phone?	<input type="text"/>	<input type="text"/>
18. by email?	<input type="text"/>	<input type="text"/>
19. using collaboration tools (e.g., NetMeeting, PC Anywhere, etc.)?	<input type="text"/>	<input type="text"/>

In a typical week, how many times do you communicate with co-workers on this project about work related matters:

20. face-to-face?	<input type="text"/>	<input type="text"/>
21. by phone?	<input type="text"/>	<input type="text"/>
22. by email?	<input type="text"/>	<input type="text"/>
23. using collaboration tools (e.g., NetMeeting, PC Anywhere, etc.)?	<input type="text"/>	<input type="text"/>

24. Estimate the number of days you spent at each of the following sites **during the previous six months (May 1, 2000 - October 31, 2000)**. Please enter the number of days by each site. **Leave the site of your primary office blank.** Enter zero for sites you did not visit.

a. <input type="text"/> Germany	<input type="text"/>
b. <input type="text"/> Michigan	<input type="text"/>
c. <input type="text"/> Michigan	<input type="text"/>
d. <input type="text"/> Illinois	<input type="text"/>
e. <input type="text"/> France	<input type="text"/>
f. <input type="text"/> Germany	<input type="text"/>
g. Any other place not listed:	<input type="text"/>

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Survey on Geographically Distributed Work at Borg Warner - Netscape

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25. Indicate the frequency of your work-related communication across all modes (e.g., face-to-face, email, phone, etc.) with the following sites **during the previous six months (May 1, 2000 - October 31, 2000)**. Leave the location of your primary office blank.

	Never	A few times a year	Once a month	Once a week	Once a day	More than once a day
a. [redacted], DE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b. [redacted], MI	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c. [redacted], MI	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
d. [redacted], IL	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
e. [redacted], FR	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
f. [redacted], DE	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
g. [text input]	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
h. [text input]	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please think about the [redacted] project with which you are most involved. In this section, we are interested in feelings about [redacted] co-workers. For each statement please indicate your level of agreement.

I trust that my fellow [redacted] team members...	Local Co-workers	Distant Co-workers
26. will keep the promises they make.	-- Select from here --	-- Select from here --
27. are competent in performing their jobs	-- Select from here --	-- Select from here --
28. express their true feelings about important issues	-- Select from here --	-- Select from here --
29. care about my well-being	-- Select from here --	-- Select from here --

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30. can contribute to the success of our organization	-- Select from here --	-- Select from here --
31. care about the future of our organization	-- Select from here --	-- Select from here --
32. have consistent expectations of me	-- Select from here --	-- Select from here --
33. would acknowledge their own mistakes	-- Select from here --	-- Select from here --

Please continue to think about the [redacted] project with which you are most involved. In this section, we are interested in the quality of information exchange with [redacted] co-workers. For each statement please indicate your level of agreement.

	Local Co-workers	Distant Co-workers
34. It is difficult to schedule common meeting times with my co-workers.	-- Select from here --	-- Select from here --
35. My co-workers provide timely information about changes in current plans.	-- Select from here --	-- Select from here --
36. People I need to communicate with are difficult to find.	-- Select from here --	-- Select from here --
37. I pass on new information to my co-workers that I think will be useful to them.	-- Select from here --	-- Select from here --
38. My co-workers pass on information that they think might be useful to me.	-- Select from here --	-- Select from here --

Please continue to think about the [redacted] project with which you are most involved. In this section, we are interested in delays you have experienced involving your [redacted] co-workers.

	Involving Local Co-workers	Involving Distant Co-workers
39. How many times in the past month was your own work delayed because you needed information, further discussion, or a decision?	<input type="text"/> times	<input type="text"/> times
40. What was the average length of the delays you experienced before acquiring the needed information.	--Select from here--	--Select from here--

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APPENDIX K: EXCERPTS FROM INTERVIEWS

Interview citations

1. "In terms of communicating with distant sites, we primarily visit Germany because other efforts at coordination have not been successful. With other groups we have used electronic transfer media. We would get together maybe once a month or so and have regular weekly telephone meetings to discuss the project. One problem with Germany is that they're not very Internet friendly. We tend to find we have to actually go there to do the work. They want that – in order to learn from us, it's better for them if we're available to answer questions. This is the main difference with this project, compared to others in distant sites."
2. "We usually work with experienced transmission guys who pick up on it right away. This is not true of the Germans. These guys are still trying to find their common path, and are still bouncing off the walls a little bit. We recently instigated conversations with (the project team director) and (the most senior manager at the German site) to talk about what each of us do wrong, and how we can work with that. We are trying to get over the stage where our guys feel used, and their guys feel like we get all the glory."
3. "Distance is a problem: The activity is happening in Europe, but (the Division B US location) needs to participate in this 'global engineering exercise.' In the future of the project, the bulk of the work needs to be done here. We will test equipment here, and will need to increase the amount of work done in (the Division B US location). We need to figure out how to do it -- coordinating development, testing, and communication between (the Division B US location) and (the German product development location) better ..."
4. One participant described his role in the CAR team as follows: "Originally, one of the principals at (the company), who used to be one of the bosses (of the company) in Australia, and 5 people at (the subcontracting company) were part of their team. When this project came up, the German product development location was not a transmission design group. (The boss) said he needed someone to coordinate these guys (in the German location) to come up with the concept, like an outside consultant to make sure they were heading down the right road. In the past (our subcontracting company) has fully handled one two or three of these types of projects at the same time. [Interviewer question: why wouldn't you do this all by yourself, then?] (The boss) didn't want someone to take the project over. Instead, we're holding their hand, and doing it at a premium, passing knowledge to them. Later, we formed a joint venture to continue this project, between (the company) and (our subcontracting company). We were not bought by (the company), but we signed a contract to give X amount of resources to them for three years, and to ensure them that we won't go to competitor, and if we did, they would have a months to compete with competitor – retaining experienced people here."

5. He continues by saying that the Americans consider the subcontracting company to be related to the parent company, however, "the Germans don't consider us to be a real part of the group because we haven't been bought by (the company). This has been an issue from the start. The US people see us as part of the team, but Germans don't treat us as if we are part of the team at all... In terms of my role on the project, the US side has told me I'm the technical project manager. However, the Germans say I'm a hydraulics consultant."
6. "One of the most difficult things about working with Germany is the language problem. It's not so much in spoken English, its more in cultural things. They work a little differently. Its easier with the Japanese – they have a structure where the decisions come from the bottom and are passed up. They'll have a meeting, come to a conclusion, pass it up to the next level, and by the time it reaches the more senior person, he might have a few questions, but he doesn't really get involved. He lets the workers do their jobs. This structure is very suitable for engineering work. With the Germans, I haven't figured out how they do it. There are people with ideas flying around everywhere. For instance, I have never seen a formal test report or test request. It may be that they're worried about showing them to us (that we'll steal their ideas) – so they may actually have test printouts. But they didn't seem to have a formal testing and reporting process. They seemed to rely more on people's opinions and ideas, and who's the most powerful debater in the meeting. I'm also not sure if it's just this company. They're used to supplying a proven production part, not new mechanisms where many things can go wrong. Maybe it's a learning curve that they just need to climb. The Japanese were developing transmissions, and they understood what we were talking about – they were in the business – that was a big advantage. Same with Detroit: they understand the US motor industry and have a more similar culture."
7. "Some of cultural differences – their decision-making process is different than how we would do it. They work more on a group consensus (Germans) attitude where the US individual will take responsibility and push things forward, and push things quickly along, where here it takes a little bit longer in the beginning. They deny it, but I see it now more and more. And there's a difference between the younger and older generation – older generation (of Germans) goes more towards consensus, younger tend to be more independent."
8. "Things that have been most difficult – I would have to say the different levels and types of software used. CAD packages, flowchart packages, word documents -- getting them all on common ground. This is a problem for (the company) and its customers too."

9. "We've run into trouble because they get new software but don't update us at all about it. Normally with others we decide which software we'll use, and then don't change it during the project. The Germans are using brand new software, which needs to get deciphered for us to use it – its ProE, mechanical desktop version 6 or 2. Some of the new 3D packages can't be saved as a lower version, and this causes problems when updating arbitrarily."
10. "They (engineers at the German product development site) are getting used to using the Internet. I'm seeing a problem on the higher managerial side – there seems to be no drive from the upper managers to at least catch up with the technology. They're not propagating that through the group (the importance of the technology). They're failing to believe that the world is changing and that information technology is there to improve performance. They are not willing to accept this. There is not one single managerial person with a deep level of technology knowledge, all managerial people there are shy of using technology. This is a problem too the level of the person who's in charge of the whole group does not know how to use his own email -- pretty scary!"
11. "There is no person who is preaching IT there, who might have training sessions, etc. Like POGP secure email. They could set it up, explain that this is a secure web site, and invite people to have a look. It's a small group, you could easily set them up around a computer for a half hour. 90 % of the engineers would want to use it, but they have no one setting up the training. They would probably love to use it and try it. Doesn't take that long to get them to use it. They just need a drive from management to support electronic information exchange. The managers have more meetings than working days – on our end, we end up canceling our formal meetings, but everything is cross- distributed over email, but over there its all happening over the table. But then again, it's not a (German) cultural thing, because at (another large automotive company) everything happened over email. They have a formal email distribution list even, to send the email out."
12. "Working with one of the German sites was most difficult. They were not flexible. People from (another large automotive company) in Germany were well aware of Internet services, had access to all tools, and were willing to use new tools. If we set up a web site, they would try it, they would work with us. In the Germans site, the people in the length of the project never even got to use the Internet site. They tried it, but gave up on first attempt. The IT group over there was not very efficient, but at the same time, they were lacking the basic knowledge of things like windows explorer – how it works. I heard lots of complaints from them about their IT people and lack of responsiveness. But I noticed too that they would try themselves, fail to get anywhere, and then not ask the IT group for help. I don't believe that the IT group when they installed the computers, set them up correctly for complex things, like more secure service. I sensed that they never thought the Internet was something serious, which is very unusual. They only got desk-to-desk email 6 months

ago. ... the German site is the only group of people where we're failing on international interactive engineering (we have even worked with other groups in Germany)."

APPENDIX L: INTERVIEW PROTOCOL

Interview Protocol

1. Explain the purpose of the interview
 - To understand the problems of multi-site coordination in design engineering.
 - To learn from your experiences and develop constructive feedback.
 2. General questions.
 - What are your responsibilities in the CAR team?
 - Which project(s) do you spend most of your time working on?
 - How long have you been part of the CAR team?
 - How often do you contact fellow team members at other sites? What media do you use to contact them?
 3. Communication
 - What is the nature of planned, shared communication (like weekly status meetings). How are these conducted? Is this satisfactory?
 - What is the nature of unplanned communication – how do you contact people you need to reach? Can you find the right people? Which tools do you use to help? Do you have any frustrations with these?
 4. Work flow
 - How is work on your project(s) divided among the sites?
 - Who is involved in planning and implementing design changes?
 - How are task assignments and changes communicated?
 5. Problems and opportunities for improvement
 - What is the most difficult thing about working with people in multiple sites?
 - Can you think of specific problems that have come up?
 - Are there any practices that you find valuable for multi-site work?
 - What tools and technologies do you find most helpful?
- Additional questions for Managers:
- For those who report to you, what would a typical work assignment be?
 - How often do employees change projects?
 - What is your background?